Chinook Salmon and the Environmental Water Account: A Summary of the 2002 Salmonid Workshop

By

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Prepared for the

CALFED Science Program
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October 2002
Sacramento, California

Acknowledgments

We would like to thank presenters at the 2002 salmonid workshop for taking time to review our draft descriptions of their presentations and for providing their PowerPoint slides for use in this paper. In particular we want to thank Jim White, Alice Low, Bruce Oppenheim, Sheila Greene and Pat Brandes for their comments on the draft.

Introduction

Agency biologists convened the second annual Environmental Water Account (EWA) salmonid workshop, held in Sacramento, California, on July 23 and 24, 2002 (see Agenda, page 46). The workshop was organized to deal specifically with salmonid-related EWA activities during the period October 2001 through June 2002, but also provided information about Chinook salmon life history, including factors that control their distribution and abundance.

The workshop goals and objectives, as developed by the agency biologists were:

- Goal:
  Improve the use of the EWA to protect fish.
- Objectives:
  Provide updates on EWA use in past two years and what may be needed next year.

  Respond to recommendations made in 2001 year by agency biologists and the EWA review panel.

  Present and discuss new information and hypotheses.

  Seek ideas on experiments to clarify the science behind the EWA.

This report is intended to document the key points made in the workshop. The intended audience includes Sam Luoma (CALFED Lead Scientist), workshop attendees (see List of Attendees, page 47), other fish biologists and the EWA review panel. The report was drafted by the authors, reviewed by workshop presenters and many of their comments incorporated. The authors are responsible for final selection of material included in the summary and any conclusions drawn from the material. The material is not organized in the same sequence as occurred in the workshop—in particular the discussions on the second day have been incorporated with the appropriate topic from the first day. For example, the Juvenile Production Estimate (JPE) presentation on the first day is followed by a distillation of the second day's discussion of the JPE.

This workshop report focuses on Chinook salmon. There is a second 2002 report summarizing a September 4, 2002 delta smelt workshop. For a more complete background on the key fish species (all four Chinook salmon races, steelhead rainbow trout, delta smelt, Sacramento splittail, and green sturgeon) and some features of the San Francisco Estuary (Estuary) see Brown and Kimmerer 2001a. (This reference is also posted at http://calfed.ca.gov/Programs/Science/Science.shtml.)

We have included two maps (Figures 1 and 2, respectively)—one showing key features of the Estuary and the second showing the river features and sampling locations mentioned in the text to help readers better understand the often rather cryptic references to locations. In addition, we have included a limited amount of information not included in the presentations, generally related to a key program mentioned somewhat in passing by the speaker. Inclusion of supplemental information is intended to assist those readers not working in the system. In a final section we summarize our reaction to the workshop itself and where we may need additional scientific efforts.

Although the EWA is briefly described later (and has been described in detail previously—see for example, Jim White et al. 2001, and Brown and Kimmerer 2001b and 2001c) it may be worthwhile to introduce its basic purpose here. The CALFED Bay-Delta Program—a collective effort by state and federal agencies and stakeholders—has been established to restore the environmental integrity of the San Francisco Estuary and its supporting watershed and, at the same time, work to assure the reliability of that portion of the State's water supplies diverted from the Sacramento-San Joaquin Delta. As described in the 2000 CALFED Record of Decision (ROD, see http://calfed.ca.gov/html for more information on CALFED and the ROD), the EWA is a key component of both the environmental protection and water supply reliability elements of the overall plan. By use of EWA funds and other measures, CALFED can acquire and store water for later use. If the fish agencies determine that a reduction in water exports will provide needed fish protection, pumping can be modified and the water supplies lost would be made up from stored EWA water.

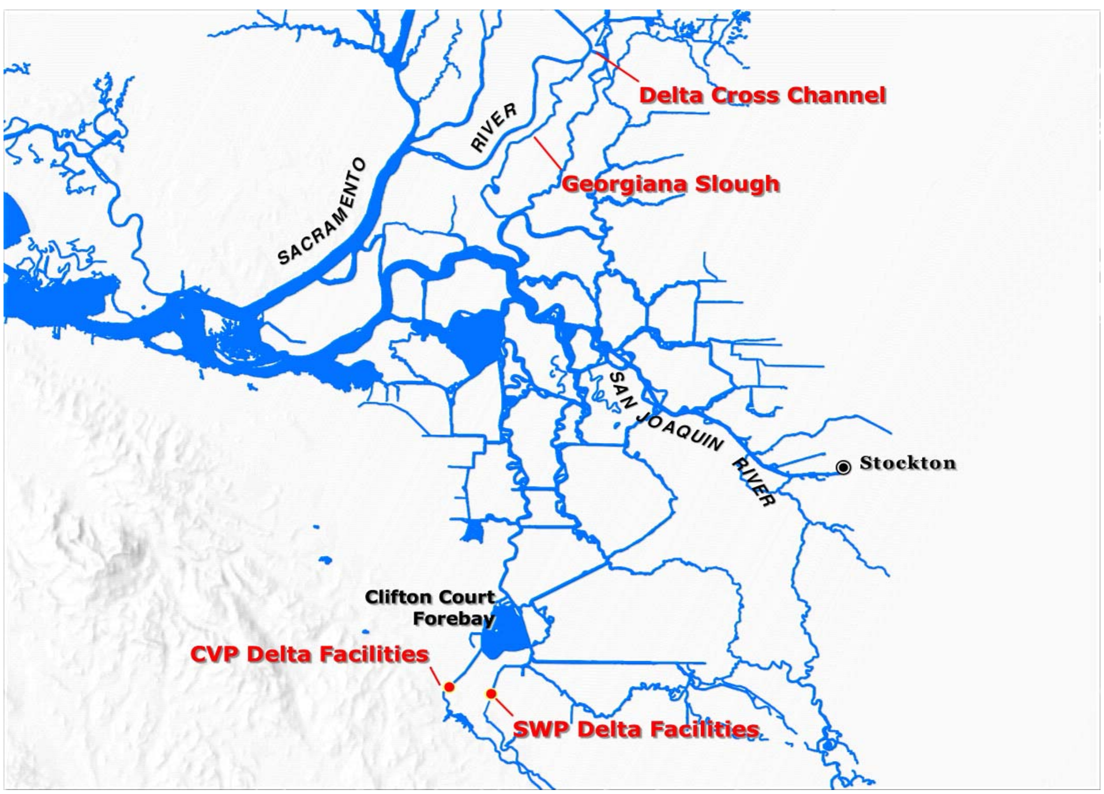


Figure 1 Map of the San Francisco Estuary, northern reaches. Source: Alice Low, DFG.

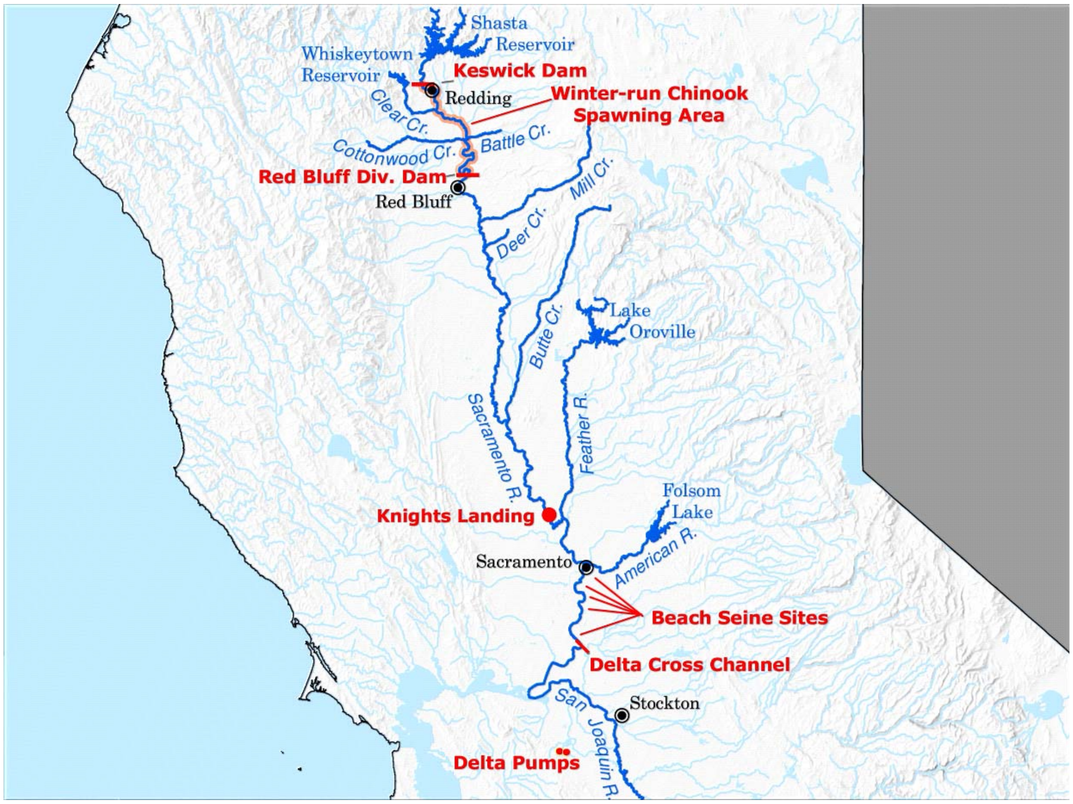


Figure 2 Map of the Sacramento River, Shasta to the Delta. Source: Alice Low, DFG.

The Environmental Water Account

Jim White of the California Department of Fish and Game (DFG) provided background on the Environmental Water Account. Although extensive background material can be found in several reports from last year, a few of the important features are included here to provide readers with a general understanding of the purpose of the EWA and how it functioned in 2001–2002.

As described by Jim, the EWA:

- Is part of the CALFED Bay-Delta Program's Water Management Strategy.
- Provides protection to the fish of the San Francisco Estuary through environmentally beneficial changes in the operations of the SWP and CVP, at no uncompensated water cost to the projects' water users.
- Obtains EWA water through purchases and other operational agreements.
- Uses EWA water to replace project supplies interrupted by actions to protect fish.
- Will provide sufficient water, when combined with the Ecosystem Restoration Program (ERP), Environmental Water Program (EWP), and the regulatory baseline, to address CALFED's fish protection and recovery needs. The U.S. Endangered Species Act and

California Endangered Species Act (ESA, CESA) commitment is that there will be no uncompensated reductions, beyond existing regulatory levels, to protect listed fish. (Note that the EWP has not provided any water to date.)

- Will be renewed annually for four years and will be evaluated before determining if the program should be continued, and, if continued how it should be modified.
- Will reduce conflicts between fish protection and water supply reliability needs and will put listed fish species on a recovery trajectory. Use of EWA assets is expected to have multi-species benefits.

The regulatory baseline includes all actions, regulations, and opinions in place to protect and restore sensitive fish species, including water quality control plans, biological opinions, and relevant sections of the Central Valley Project Improvement Act (CVPIA). The ERP contains a Environmental Water Program (water purchases) that, although not yet operational, will provide water to protect fish.

The regulatory baseline is the so-called Tier 1 in the EWA. Tier 2 contains the EWA and the ERP, including the EWP. There is a Tier 3 protocol established to purchase water beyond Tiers 1 and 2 (for extraordinary situations above and beyond the capabilities of Tiers 1 and 2), but it was not used in the first two years of the EWA.

Jim described the period when EWA fish actions may be needed, generally October through June. The following provides a more detailed description of the expected timing based on individual species.

- Yearling spring run and other juvenile Chinook salmon emigrate through the Delta in fall and winter months.
- Juvenile winter Chinook emigrate mainly in winter months.
- Pre-spawning adult delta smelt are in the Delta in winter and spring.
- YOY delta smelt are in the Delta in winter and spring.
- Juvenile steelhead emigrate in winter and spring.
- Spring and fall Chinook smolts emigrate through the Delta in winter and spring.

Implementing EWA actions in 2001–2002 involved the relatively complex interaction of data collection and posting, data interpretation, recommendation development, action on recommendations, and making the process and actions transparent to stakeholders and other interested parties and individuals. The process is briefly summarized below.

1). *Data collection and posting.* The fish agencies, water project agencies, and local agencies provide the basic data used by the EWA and other processes. The data are made available by posting on websites, or sent via fax or e-mail. These data include such disparate measurements as:

   a). Fish abundance at several sites in, above, and below the Delta.

   b). Recent past, present, and projected water project exports.

c). Estimated entrainment and incidental take of several key fish species at the project pumps.

d). Forecasted precipitation and flows in the watershed and into the Delta.

e). Tides and their effects on internal Delta flows.

f). Status of internal Delta barriers, such as the Delta Cross Channel and the south Delta temporary barriers.

g). Environmental variables such as water temperature, salinity, and turbidity.

2). *Developing recommendations.* The Data Assessment Team (DAT) is the primary forum for developing recommendations for use of EWA assets. DAT consists of individuals representing the management agencies [MAs: U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS) and DFG], the projects agencies [PAs: U.S. Bureau of Reclamation (USBR), Department of Water Resources (DWR)] and stakeholders from environmental and water communities. DAT generally meets once each week by conference call to consider the available data and to determine if actions are needed to protect sensitive fish. (DAT may hold conference calls more frequently than weekly when rapidly changing conditions warrant increased attention.) Decision trees are available for salmon and delta smelt to assist in developing recommendations to modify exports, adjust stream flows through releases from upstream reservoirs or modify barrier operations. The delta smelt working group (agency and stakeholder representatives) may be asked to consider information and develop recommendations specific to this animal. A b(2) interagency team (B2IT) generally meets weekly to help integrate EWA and allocation of the federal water in the Delta and upstream areas.

3). *Taking action*. DAT passes recommendations to the Water Operations Management Team (WOMT) and many of the DAT members also attend its weekly meetings. WOMT, consisting of management level representatives of the fish management and water agencies (no stakeholders), considers the recommendations in view of the EWA assets available and projected operations. In almost all instances, the recommendations are approved, although in some cases, the timing maybe slightly modified to fit better into operational schedules. DWR staff uses projected operations to estimate water costs of the action taken and keeps track of accretions and depletion to the EWA account. At the end of the year DWR and the USBR reconcile account of changes to scheduled pumping and other actions to arrive at a statement detailing the acquisition uses of EWA water.

4). *Informing stakeholders.* If stakeholder input is needed for a specific action, the agencies may ask that the Operations and Fisheries Forum be convened to consider biological and operations data. As appropriate, EWA actions are included on the monthly agenda of the CALFED Operations Group to keep stakeholders informed.

5). *Annual review.* The salmonid and delta smelt groups hold annual workshops to discuss EWA use in the previous season. In addition, each fall the CALFED Science Program convenes a panel of outside experts to review EWA program progress and suggest modifications that may improve resource allocation and fish protection.

The fish management agencies expect that:

- EWA water will be available as described in the CALFED Record of Decision.
- The operational tools will be fully functional, for example, to change diversion from the state to the federal pumps, Joint Point of Diversion or JPOD, if warranted to protect fish. (Note that the State Water Resources Control Board (SWRCB) has to approve the JPOD.)
- Fish protection and ecosystem benefits beyond the baseline will be achieved, thus contributing to species recovery.
- EWA water will be adequate to deal with incidental take of listed species at project diversions from the south Delta.
- The ESA / CESA commitment to protect fish above existing regulatory requirements will be fulfilled without affecting water supply.
- Water quality impacts in the Delta due to EWA management will be avoided.

Use of the EWA to Protect Salmonids, 2001–2002

Roger Guinee of the USFWS described fish-related EWA actions occurring during 2001–2002. In many instances the actions were taken specifically to benefit more than one species. In general, a relatively high winter Chinook allowable take level and the low take at the pumps in 2001–2002 made the second EWA season much more relaxed than the first.

An essential part of the EWA program is to acquire water, often upstream of the Delta. This water is eventually moved south of the Delta where it is either turned over to one of the project agencies at O'Neill Forebay if there is a water debt, or stored in San Luis Reservoir to pay for future EWA actions. To the extent possible, moving the EWA water is timed to benefit instream uses, or at a minimum, to not harm fish in the streams or the Delta. Timing the transfers is complicated by the need to move the water south by use of the Delta pumps. Roger listed three transfers that affected upstream areas, and that were coordinated to benefits the streams while minimizing Delta impacts.

- Approximately 150 thousand acre feet (TAF) of water stored behind Englebright Dam on the Yuba River and purchased from the Yuba County Water Agency. Transfers occurred from July through October 2001 with the transferred water stored in San Luis Reservoir. In transfers across the Delta, some water is assumed to be lost in the process, thus the actual amount stored is always less than the amount purchased, usually on the order of 15% - 25% less, depending on Delta conditions when the water is moved.
- Water in Lake McClure on the Merced River purchased from the Merced Irrigation District. Water was transferred from upstream, through the Delta to San Luis Reservoir during the October through December 2001 period.
- Water purchased from the Placer County Water Agency and briefly stored in Folsom Reservoir. The water was moved down the American River, and through the Delta, to San Luis Reservoir during the October through November 2001 period.

In a somewhat new action involving the EWA, the use of EWA power credits obtained from earlier reductions in Delta pumping allowed the USBR to bypass its turbines at Folsom Dam to allow additional cold water to be released to the lower American River in November 2001. The cold water provided for better spawning conditions for the large numbers of fall Chinook returning to the American River.

In February 2002 the low abundance of Chinook salmon, steelhead, and delta smelt at the pumps allowed the fish agencies to elect to temporarily relax the export:inflow (E:I) ratio. The resulting increased pumping in excess of the 35% limit in the Bay-Delta Water Quality Control Plan (WQCP) was credited to the EWA and the 76 TAF was stored in San Luis Reservoir. Three TAF were obtained in a brief E:I relax action in November 2001.

The following actions were requested by the fish agencies to reduce the impacts of project pumping to sensitive fish resources.

1). *January 5 through 9, 2002.* The aggressive action to reduce SWP pumping to 1,500 cubic feet per second (cfs) for a 5-day period was taken primarily to protect maturing delta smelt, but was expected to benefit salmonids as well. The EWA cost was approximately 66 TAF.

2). *April 15 through May 15.* EWA water was used to reduce exports to levels called for in the Vernalis Adaptive Management Plan (VAMP) - a long-term study of the interaction of San Joaquin River flows and Project pumping on survival of juvenile Chinook salmon emigrating from the San Joaquin River basin. Although VAMP is primarily an experiment, reductions in pumping and increased stream flows can reduce entrainment losses of all Delta species. Approximate water costs to the EWA were approximately 45 TAF.

3). *May 16 through May 31.* EWA water was used to maintain a combined pumping rate of 1500 cfs to extend the period of and reduced entrainment loss and more favorable Delta conditions for migrating salmon, delta smelt, and other Delta species. The EWA costs of these so-called “shoulders on VAMP” were approximately 131 TAF.

4). *June 1 to June 2.* The fish agencies requested that DWR and USBR ramp up gradually from VAMP pumping levels to levels allowed under the Bay-Delta WQCP. The gradual increases protect Chinook salmon and steelhead, but were primarily intended for delta smelt protection.

In October 2001 the EWA went into the season of fish concern with approximately 84 TAF of available water. During the season, the EWA acquired an additional 324 TAF, either by direct purchase, relaxation of the E:I ratio, or other means (not counting for carriage water losses from north of Delta purchasers, conveyances, losses, etc.). Fish actions in 2001–2002 cost the EWA a total of 285 TAF (including the conversion of 38 TAF into a pumping curtailment as San Luis Reservoir was filled, but not including 40 TAF that, instead of converting to an export curtailment, was provided to project water users in exchange for 20 TAF returned to EWA later in the year, leaving a balance for next year of approximately 63 TAF). This overly simplistic representation of EWA accounting is provided to give a general idea of the amounts of water used and available. DWR and USBR operation staff will prepare a much more complete end-of-year accounting of the EWA costs and acquisitions.

The Salmon Decision Tree

Sheila Greene of the California Department of Water Resources (DWR) described the decision tree used by agency biologists and project operators to help develop recommendations for allocation of EWA assets. In the 2000–2001 emigration period there was an explicit salmonid decision tree for the October through January period and an extension under development for the February through March period. Because of unexpected high winter Chinook take at the state and federal pumps, the January through March 2001 decision tree was explicitly used to recommend allocation EWA water. As Sheila pointed out, the decision tree is a guidance document, not an inflexible, mechanistic process for arriving at operational changes. The decision tree is also a working document and, as such, is expected be modified as biologists learn more about the salmon and how they use the riverine and estuarine environment.

Figure 3 shows the decision tree process in place for the 2001–2002 October through March emigration period. Note that the decision tree no longer applies to juvenile Chinook salmon in the length range of 70 to 150 mm, but to all juveniles larger than the lower end of the winter Chinook size range—the so-called older juveniles—which include winter and spring Chinook yearlings from Mill and Deer creeks. The first alerts involve catch data and deal with status of the Delta Cross Channel gates from October 1 through January 31. (The fish biologists can request up to 45 days of gate closure during this period. From February 1 through May 20 the gates remain closed to protect emigrating salmonids. The biologists are developing new criteria for opening the gates for 2003. The criteria for closing the gates are expected to remain unchanged.) The second set of alerts involves actions that can reduce Delta pumping. The primary objective for pumping reductions is to reduce incidental take of older juveniles, including winter Chinook, at the Delta pumps.

Due to the low salmon take at the pumps this past season, and relatively low numbers of older juvenile salmonid in the river catch, the salmon decision tree was used less frequently in 2001–2002. Sheila proposed that biologists consider modifications before the 2002–2003 emigration season, modifications that involve how catch indices are calculated, use of flow data in the decision tree, and the size classification of fish used in the decision tree process. Sheila also described some preliminary analyses linking salmon movement into the Delta with river temperature and flow in the Sacramento River at Wilkins Slough. (Analysis of the past few years indicates that a water temperature of 13.5 degrees C may be significant and could act with flows of greater than 7000 cfs to trigger salmon movement.) The salmon biologists will refine the decision tree and present the modifications to the EWA panel in October 2002.

Discussion of Salmonid Decision Tree

The discussion occurred during and after Sheila's presentation on the first day and during a specific discussion period on the second day. Meeting participants raised the following points in the discussion.

1). Responses of agency biologists to 2001 recommendations of EWA Science Panel that relate to decision tree.

- a). Define error bars around JPE. (This is being worked on.)
- b). Use formal risk assessment to evaluate decision process. (Nothing has been done to date because of lack of staff with training in risk assessment.)
- c). Use cumulative catch indices to assess actions. (Agency biologists do not believe this consistent with decision process.)
- d). Document decision tree criteria. (Although this has been done to some extent, it may need more work and perhaps with the documentation posted on a website.)

2). Use of catch indices beyond January may be difficult because fish are growing and may change the index values.

3). Available data indicate there is no relationship between JPE and catches in the lower river and Delta.

4). During the October through January period, both fish protection and water quality needs must be considered when closing the cross-channel gates.

5). There needs to be more discussion and data analysis in response to a suggestion that the Wilkins Slough flow trigger be replaced by fish catches. Some folks in the audience believed that flow changes trigger fish movement.

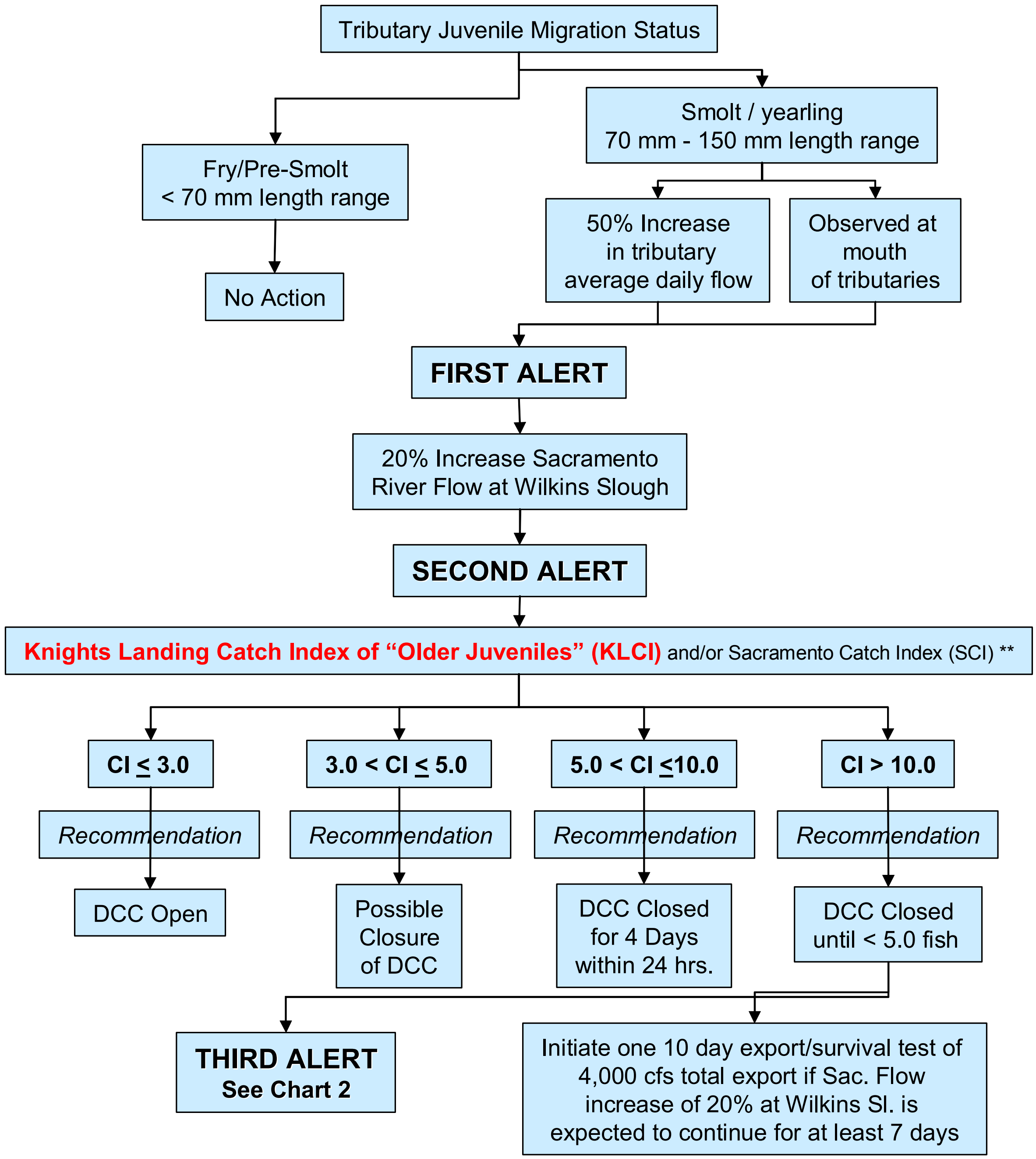
6). There may be a need to incorporate population data, and the percent of the population at risk, in the decision tree.

7). Need to consider other data in the decision process—for example, the Balls Ferry (immediately downstream of the primary spawning area), Glenn-Colusa Irrigation District (already considered, albeit without specific criteria) and Red Bluff Diversion Dam screw trapping (not available the past two years).

8). Need to consider how to standardize gear efficiency or at least understand the range of efficiencies of the gear being used.

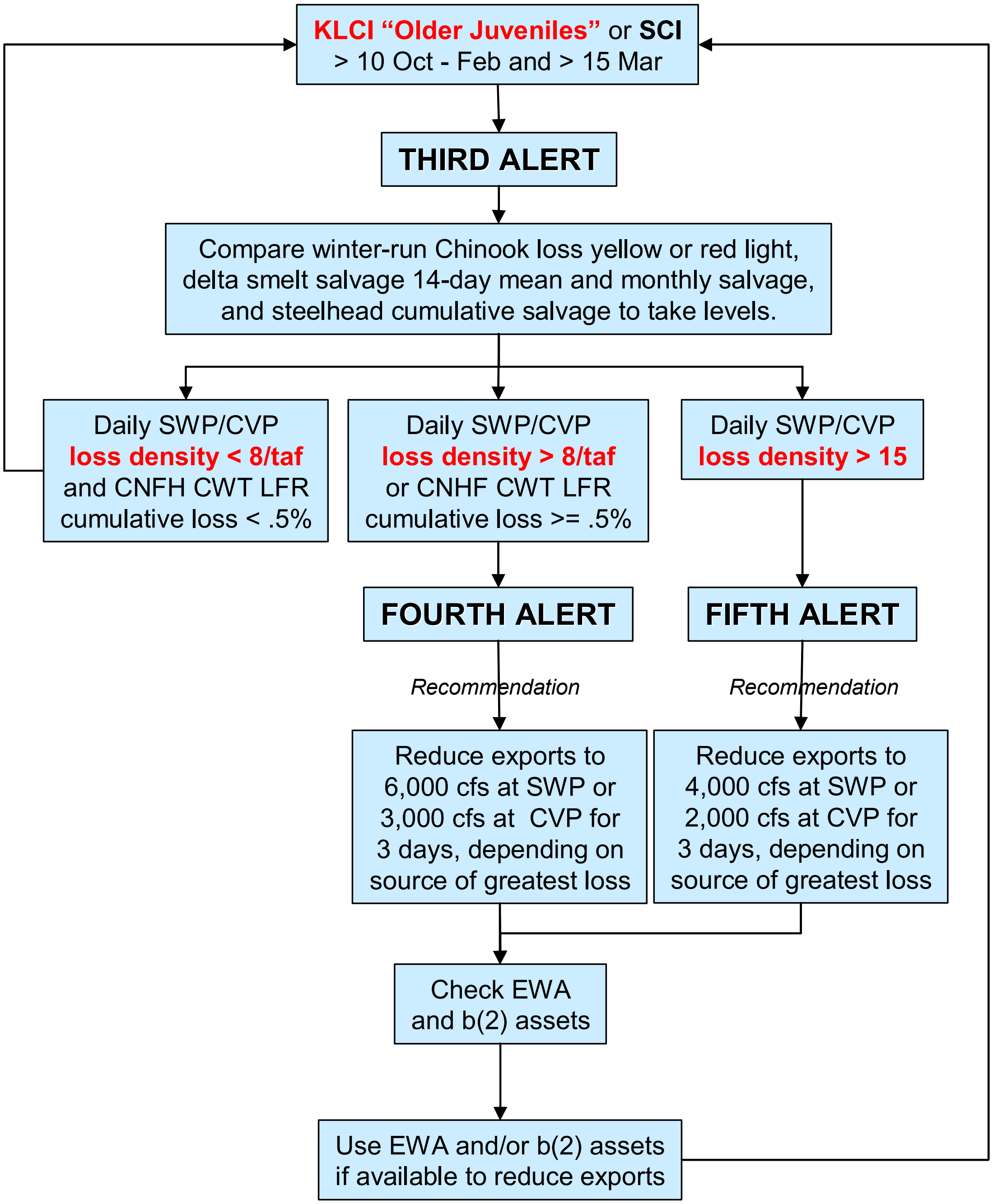
9). Need to consider expanding use of flow and temperature measuring and modeling tools.

10). Consider use of other monitoring techniques such as hydroacoustics.



2001/2002 Chinook decision process October through March (Chart 1).

Figure 3a Salmonid decision tree used in 2001-2002. Source: Sheila Greene, DWR.



** Effort standardized to on 24-hour trap day for Knights Landing Catch Index, and*
10 trawls and 8 beach seine hauls per two-day sampling period for the Sacramento Catch Index.

2001/2002 Chinook decision process October through March (Chart 2).

Figure 3b Salmonid decision tree used in 2001-2002. Source: Sheila Greene, DWR.

The Juvenile Production Estimate (JPE)

This summary of the JPE is organized around the presentation made at the workshop by Bruce Oppenheim of NMFS and a summary of the discussion about the JPE held on the second day. Recommendations developed by the group are included at the end of the JPE summary. Finally, we have included some information about two upstream studies that figured prominently in the discussion but which were not described in any detail by the presenters or attendees.

The JPE is an integral component of the NMFS/DFG regulatory process designed to maintain acceptable levels of CVP and SWP induced direct and indirect mortality of juvenile winter Chinook in the Sacramento-San Joaquin Delta. The JPE provides an estimate of the numbers of juvenile winter Chinook expected to reach the Delta. The combined calculated incidental take (loss) of winter Chinook at the Delta Fish Facilities is then set at 2% of the JPE—the so-called "red light" level. (See Brown and Kimmerer 2001b for a brief description of take.) When project estimated take exceeds 1% of the JPE (the warning or "yellow" light level), project operators and fish agencies through CALFED Ops, must convene to explore additional measures to reduce take. If the combined calculated incidental take at the projects exceed the 2% level, they are to formally consult with NMFS and DFG. The take limit was originally set at 1% of the JPE, but NMFS subsequently increased it to 2% to allow, in part, for the uncertainty in accurately identifying juvenile winter Chinook at the Delta salvage facilities. The 2% limit for direct loss at the project intakes provides an incidental take authorization for juvenile winter Chinook that die in the Delta as a result of project impacts (including increased in-Delta mortality resulting from project-induced changes in flow patterns, increased predation, increased water temperatures, and decreased food supply), not just direct losses at the project intakes.

The JPE consists of a series of calculations using estimated adult escapement, sex ratio, fecundity, and survival from egg deposition to smolt emigration to arrive at estimated juvenile winter Chinook production. As shown at the 2001 EWA salmonid workshop, the calculation process had remained relatively unchanged since the early 1990s. Information presented at the workshop, as summarized by Brown and Kimmerer (2001b) indicated that new information was available to change almost all components of the calculations. The workshop summary and the report to CALFED by the EWA review panel recommended that NMFS and DFG seriously consider revising the JPE to better reflect our understanding of its components.

Table 1 illustrates the calculations used to estimate that almost two millions naturally produced winter Chinook would reach the Delta during the fall and spring of 2001–2002. As also indicated, 252,684 hatchery winter Chinook were released from the Livingston Stone National Fish Hatchery (LSNFH), located at the base of Shasta Dam. The table includes some of the factors used to derive the JPE and the source of the information used to derive these factors. The 2% level for 2001–2002 was almost 40,000 fish. By comparison the JPE for 2000–2001 was less than 400,000 juvenile winter Chinook and the 2% level was less than 8,000 fish.

Table 1 2001–2002 winter-run Chinook juvenile production estimate

Total spawner escapement[a]	7,572
Number of adult females (64.4% of spawners)[b]	4,876
Effective spawner population (1% pre-spawn mortality)[c]	4,828
Estimated number of eggs (4,700 eggs per female)[d]	22,689,740
Egg loss due to high temperatures (0.5%)[e]	113,449
Total viable eggs	22,576,291
Estimated survival from egg to smilt (14.75%)[f]	3,330,003
Estimated survival of natural smolts to the Delta (56%)[g]	1,864,802
Total arrival in Delta of naturally produced fish	1,864,802
Livingston Stone propagation release (January 2002)[h]	252,684
Yellow light level (1% of naturals + 0.5% hatchery)	19,911
Red light livel (2% of natural + 1% hatchery)	39,823

a. Based on DFG carcass survey (Jolly-Seber model), includes hatchery grilse.
b. Based on observed grilse and sex ratio, DFG carcass survey 2001.
c. Estimated mortality up to 1% from fresh carcass observations, DFG carcass survey 2001.
d. Average fecundity rate from 2001 spawning at Livington Stone Hatchery (n = 50).
e. Percent egg loss, based on aerial redd surveys and upper Sacramento River temperature model.
f. Based on USFWS Tehama-Colusa spawning channel studies, 1975-1980.
g. Based on ocean recoveries of paired CWT releases from Battle Creek, 1994-1999 (USFWS 2002, unpublished).
h. All hatchery released winter-run Chinook marked with an adipose fin clip and CWT.

The changes made in JPE calculations for 2001–2002 were as follows:

- NMFS used the upper Sacramento River carcass surveys to develop estimated run size. In the past, run size had been extrapolated from the estimated numbers of winter Chinook counted using fish ladders at the Red Bluff Diversion Dam (RBDD). A comparison of the methods is found later in this section.
- The carcass survey data indicated that 64.4% of the spawners were female. In the past, a 50:50 ratio had been assumed.
- Hatchery releases were given a separate take limit.
- NMFS deleted the numbers of adults taken to LSNFH and estimated percent grilse in the run since the carcass survey provided actual data.
- Pre-spawn mortality decreased from 5% to 1% based on actual field data.
- Based on actual counts from hatchery females, NMFS decreased the numbers of eggs per female to 4,700, from the figure of 4,990 used last year. However, this is greater than the literature-derived 3,859 figure that had been used in earlier years.
- Estimated egg loss due to temperature problems of less than 0.5%.

- Instead of using two separate survival rates—one from egg to fry and a second from fry to smolt—one rate of survival to smolt of 14.15% was used. The egg to smolt survival rates were based on USFWS studies at the Tehama-Colusa Spawning Channel (near RBDD.) The 14.15% value was an average of 15 studies where the estimated survival rates ranged from 10.8% to 19.6%.
- The estimated survival of smolts migrating down the river to the Delta was 56%, as compared to the 59% used in previous calculations. The 56% was an average of differential ocean recovery rates based on tagged late fall hatchery fish releases at Battle Creek (near Red Bluff) to Ryde, Courtland, or Sacramento. The annual indices, from 1994 through 1999 releases, ranged from 0.34 to 0.90 with an average of 0.56.

Bruce discussed the significance of the JPE and incidental take limits at the pumps in the context of winter Chinook recovery and made the following points.

1). It is clear that we do not know the population level impacts of the losses of salmon to project induced factors in the Delta. It is also clear that incidental take at the pumps is not a valid index of the juvenile winter Chinook population.

2). Current trends in escapement data indicate that annual winter Chinook populations have been increasing or holding their own since a low point around 1990. Figure O1(4) illustrates estimated winter run escapement from 1967 through 2001. In the first panel, the data are plotted as untransformed values, mainly to show the dramatic change over time. In the second panel, log transformed values are plotted to demonstrate an increase in abundance. (To put this in context, the NMFS winter Chinook recovery plan calls for an average run of 10,000 females over 13 years and for a cohort replacement rate greater than 1 before delisting.) Possible reasons for this stabilization and improvement in run size since the early 1990s are:

   a). Installation of temperature control device on Shasta Dam.

   b). Changes in operation of the RBDD, which allow better passage of adults and emigrants.

   c). Mandatory closures of the Delta Cross Channel gates.

   d). Changes in Delta water project operations including the E:I ratio.

   e). Improved ocean conditions, including reduced ocean harvest due to regulatory changes.

   f). The LSNFH ESA conservation program.

   g). Installation of fish screens on many Sacramento River diversions.

   h). Export curtail to deal with high incidental take before EWA was established.

3). It may well be that existing monitoring programs can not determine the accuracy of the JPE. (In the following discussion section, we have included some information of one of the monitoring programs, juvenile abundance sampling just below the RBDD, that can help shed light on juvenile winter Chinook abundance.)

Bruce closed his presentation with a short list of additional information and analytical needs:

1). Continue to use the RBDD juvenile winter Chinook estimate as a check on the JPE. (Note that this installation was down for the past two years due to a lack of funding but it is now back in operation. Jim Smith, USFWS, personal communication.)

2). Complete more rigorous statistical analyses of the all the data sets used to calculate the JPE.

3). Produce confidence limits or range of possible values for JPE.

4). Improve accuracy of in-river survival estimates.

5). Incorporate predicted river conditions, such as forecasted fall flow releases and water temperature below Colusa, in the JPE.

Discussion of the Juvenile Production Estimate

Background Studies

To help understand some of the discussion of the JPE, we briefly describe two studies (one about estimating winter Chinook spawning escapement and the second about estimating the numbers of winter Chinook emigrants) that are closely related to the JPE. Although they were not presented specifically at the workshop, they were often mentioned. The results of these studies also demonstrate that some interesting and important work is taking place upstream of the Delta—work that needs to continue if we are to create more realistic conceptual models of winter Chinook life history. These descriptions may also help understand some of the points made in the JPE discussion.

Carcass surveys. The first of these studies concerns the Upper Sacramento River Winter Chinook escapement surveys that have been conducted annually by DFG and USFWS staff since 1996. The studies have been funded through the Anadromous Fish Restoration Program (AFRP) component of the 1992 Central Valley Project Improvement Act (CVPIA). The general study objective is to provide an alternative to the RBDD-derived winter Chinook spawning estimates—an alternative that uses the more traditional carcass survey methods to estimate salmon spawning escapement.

The results of the winter Chinook spawning surveys are documented in a series of annual reports. We selected the report about the May - August 2000 survey (Snider et al. 2001) for this summary. The need for the alternative escapement surveys is clearly shown in Figure 5, the estimated percentages of the adult winter Chinook migrating upstream past the RBDD after the first week of May each year, the period when the dam gates are now closed and fish use the ladder. Although the RBDD counts assume that 15% of the run passes the dam and is counted at the fish ladder during this period, it is apparent there is considerable inter-annual variation.

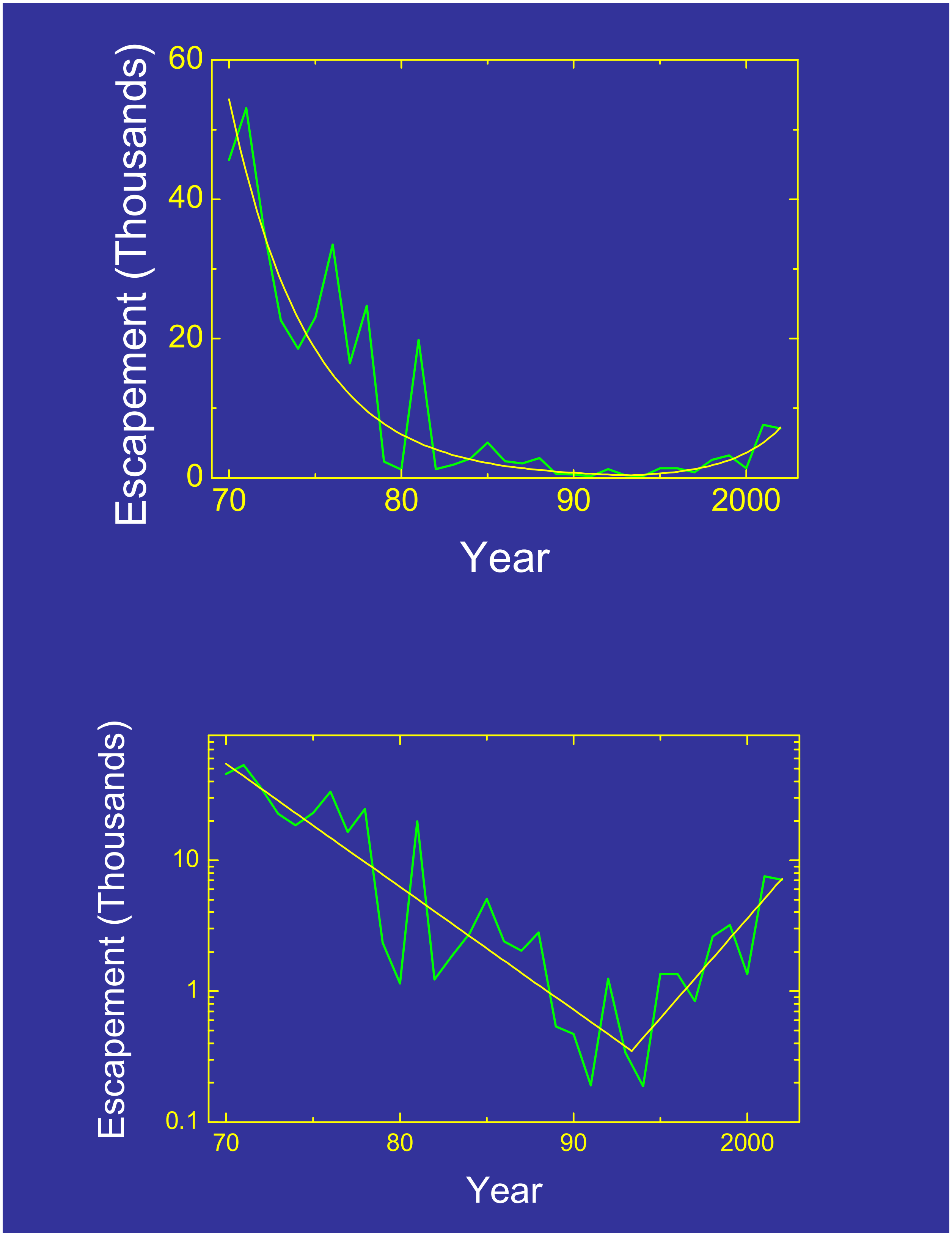


Figure 4 Estimated numbers of winter Chinook escaping to the upper Sacramento River, 1969–2001. Note that numbers are plotted on both log and arithmetic scales.

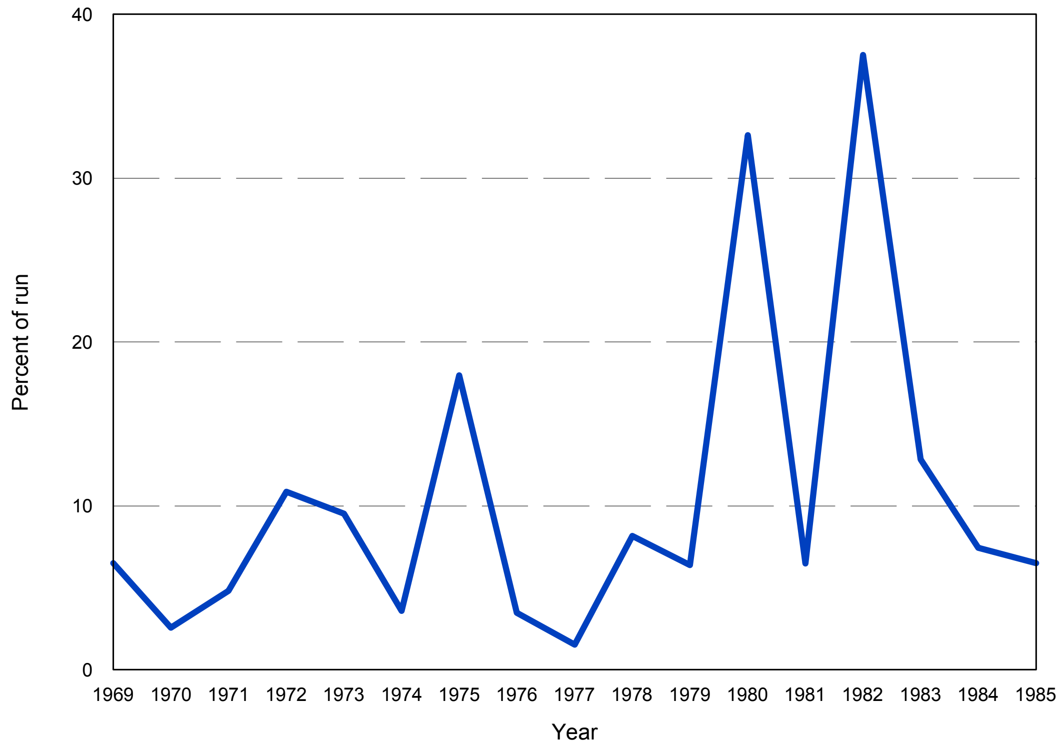


Figure 5 Estimated fraction of total adult winter Chinook escapement that pass Red Bluff Diversion Dam after May 15, 1969 through 1985. Source: Snider et al. 2001.

The study methods are rather straightforward and closely follow standard carcass survey techniques (see for example, Boydstun 1994). Some important aspects of the sampling program are:

- The sampling period is generally from May through August.
- The study area is divided into two reaches—one from RM 302 to RM 295 and the second from RM 295 to RM 288—a total of 14 river miles. Earlier studies had surveyed the 31-mile reach from Keswick Dam to Battle Creek but there were few salmon spawning and thus few carcasses to tag in the lower reach.
- The study protocol was to survey the upper reach the first day, survey the lower reach the second day, skip a day, and repeat the cycle. The 2000 study included 40 separate survey periods.
- The mark-recapture techniques consisted of tagging carcasses during one survey period and recovering the tags in subsequent survey periods. Carcasses not tagged were chopped in two. Chopped carcasses were disregarded in subsequent surveys. Tagged carcasses were returned to flowing water.
- Sex, length, and egg retention in females, among other measurements, were recorded.
- Three models can be used to estimate population—the Petersen (Ricker 1975), Schaefer (Schaefer 1951) and Jolly-Seber (Seber 1982). Each model requires certain underlying

assumptions and data. The approach has been to use all three models when the data requirements, such as tag recovery rates, are met.

Using these models, the 2000 total winter Chinook escapement ranged from 4,343 to 7,877, essentially all of which were adults (Table 2). This is contrast to the estimated 1,206 unmarked (non-hatchery) adult winter Chinook that passed RBDD.

Table 2 Summary of winter-run Chinook escapement estimates using the Petersen, Schaefer, and Jolly-Sever tag-and-recapture models made during the upper Sacramento River winter-run spawner escapement survey, May–August 2000. Source: Snider et al. 2001

	Petersen Model (fresh)	*Petersen Model (fresh and decayed)*	*Schaefer Model*	*Jolly-Seber Model*
Total estimate	6,670	7,877	5,707	4,343
Adult estimate	6,492	7,667	5,555	4,227
Grilse estimate	178	210	152	116

The difference between the RBDD estimates and those derived from carcass surveys is even more striking when one looks at a measure Snider et al. termed the "effective spawning population"—basically the total numbers of females that spawned. Using the carcass data, the total effective spawning population estimates ranged from 3,551 (Jolly-Seber) to 5,454 (Petersen). By comparison, a similar estimate from the RBDD counts was 517. In addition to differences due to dissimilar population size estimates, the divergence in estimated effective population size was due to the following factors:

- At the RBDD, 57.2% of the winter Chinook passing the ladders were called grilse (jacks, or early returning males, and some females) versus 2.7% in the carcass surveys.
- Adult females comprised 81.2% of the population from the carcass surveys, versus 28.6% in the RBDD counts.

The carcass surveys provide additional valuable information such as egg retention in spawning females (essentially zero in 2000), peak of spawning (which has varied from early to mid-June to early to mid-July over the five years) and spatial distribution of spawning. One interesting observation from the study was that the high recovery rate of tagged carcasses (greater than 40%) resulted in the ability to calculate spawning estimates in which the standard deviation was plus or minus 25% of the estimate, as recommended by NMFS (1997).

Direct observations of juvenile winter Chinook emigration from the spawning grounds. The second study involves using a series of rotary screw traps fished immediately below the RBDD. This USFWS study has been funded by the Red Bluff Diversion Dam Pumping Plant Study, an investigation into the feasibility (both economic and biological) of lifting water from the Sacramento River to the Tehama-Colusa Canal. The pumps would be used in lieu of the RBDD and would allow free passage of adult and juvenile salmonids (and other fish) past the dam site. Information for this summary is from Martin et al. (2001).

One of the study objectives was to index juvenile winter Chinook production in the upper Sacramento River using in-river quantitative techniques. The indices developed through this study were compared with the JPE, the ladder count and the carcass survey escapement estimates to evaluate possible bias in any of the estimates. The annual 1995 through 1999 broodyear production estimates were indexed using data from screw traps that fished the entire year.

Four rotary screw traps were attached directly downstream of the RBDD with traps located in river margins and in mid-channel. Traps were generally fished throughout the 24-hour period; although during high flows and high debris, abundance sub-samples were collected and the results extrapolated to the entire period. Trap efficiencies were estimated by releasing groups of spray dyed fish about 2.5 miles upstream of the RBDD. Data from the 54 trap efficiency tests were plotted against the percent of river water sampled by the traps to develop a least squares model from which daily trap efficiencies could be calculated. Daily catch and trap efficiency data could then be used to index the numbers of juveniles passing by the RBDD. The salmon growth curves were used to separate Chinook salmon by race (Fisher 1992).

Martin et al. (2001) presented a large amount of information from the five-year study. After two years of no sampling, the work will continue through 2004. A few of the more interesting winter Chinook related findings are grouped below by topic.

- *Annual variation in the winter Chinook Juvenile Production Index (JPI).* As shown in Table 3, there was considerable variation in the JPI and the confidence intervals indicated that this variation was probably real.

Table 3 Estimated number of juvenile winter-run-sized chinook salmon emigrating past Knights Landing on the lower Sacramento River, 1995-1996 through 2001-2002 (representing progeny from brood years 1995 through 2001).[a]

Emigration season	*Estimated no. winter-run-sized emigrants*	*80% confidence*
interval		
1995-1996	30,624	21,600-46,286
1996-1997	18,690	14,809-25,566
1997-1998	108,000	78.548-171,817
1998-1999	136,452	107,089-188,000
1999-2000	27,725	19,180-49,910
2000-2001	99,537	65,268-209,571
2001-2002	67,239	57,390-81,015

a. Estimates for 1995-96 through 1998-99 are "finalized" in reports; those for 1999-2000 through 2001-2002 (shaded) are preliminary and subject to revision following further analysis.

- *Timing of downstream movement of juvenile winter Chinook.* Emergence and dispersal of winter Chinook fry began in July each year and peak dispersal occurring in September.

- *Nursery habitat.* In the 5 year period, between 44% and 81% of the winter run used the area below RBDD for nursery habitat.
- *Relation of JPI to escapement estimates.* The comparisons, Figure 6, indicated that carcass survey were more predictive of the JPI than ladder counts but regressions were driven by one year. Paired comparisons between the JPE and JPI did not indicate a significant difference, but yet some evidence indicated that ladder counts underestimated the numbers of spawners.

Figure 6 Relation between juvenile production indices (JPI) as developed from rotary screw trap catch data and winter run escapement estimates from carcass surveys and ladder counts at the Red Bluff Diversion Dam. Source: Martin et al. 2001.

- *Genetic composition of carcass samples.* In 1997 tissue samples were provided to scientists at UC Davis for their analysis using microsatellite markers. Of the 239 tissues analyzed, 173 (72%) were confirmed winter Chinook. As shown in Table 4, the distribution over time indicates considerable variability in the genetic composition of Chinook salmon on the spawning grounds.

Table 4 Genetic composition of Chinook salmon carcasses collected during summer surveys

Month	*Number*	*winter Chinook*	*Percent*
May	37	18	49
June	51	35	69
July	108	95	59
August	43	25	59

Field data indicated all the salmon had spawned. The authors speculated that the other fish were spring or late fall Chinook, but genetic identification was not provided. The data indicate some plasticity in timing of spawning—a finding not too surprising since these races all now spawn below Keswick Dam in the mainstem Sacramento River.

Discussion of the Juvenile Production Estimate

The following are some of the principal points that arose in the discussion after Bruce's presentation and on the second day of the workshop.

The refinements for estimating the 2001 production made significant improvements to the estimating process, in particular the use of carcass survey data and field-determined sex ratios. There was a general request for the use of actual monitoring data to corroborate the production estimates with one of the most promising tools being rotary screw traps at various locations. To make screw traps more useful, their continuity (funding) needs to be more certain and trap efficiency estimates made routinely (as in Martin et al. 2001 and Snider and Titus 2000).

There was considerable discussion—but no agreement—on the need and capability of calculating confidence intervals around the production estimates. Suggestions were made to:

- Determine how to calculate the errors in the various components of the JPE and an overall JPE confidence interval.
- Determine how to reduce the errors of the components.
- Conduct sensitivity analysis to evaluate the importance of individual components to the total error surrounding the JPE.
- Consider other factors (for example, flow and year type) and how they may affect the JPE.
- Use loss estimates (take) at the pumps to estimate adult equivalents. Any such effort would have to include errors associated with estimating loss at the pumps and survival from smolts to adults.

One approach is to use the JPE as is, recognizing its inherent uncertainty, as part of the total data set that allows us to assess the numbers of juvenile winter Chinook that may be entering the Delta. In the long run, life cycle and cohort analysis will be the most useful approaches to setting, and evaluating the benefits of take at the Delta pumps. See Michael Mohr's presentation on page 22 for an approach to this problem.)

More work is needed on survival of winter Chinook from emergence to the Delta, and especially during the migration from the spawning to Colusa and from there to the Delta. There are indications from the data that a later emigration from the river means less survival but a wider range of flows is needed to evaluate this hypothesis.

Some tentative recommendations from the discussion were:

1). Use of a combination of the JPE and migrant monitoring when considering use of EWA assets to protect juvenile Chinook salmon emigrating from the Sacramento Basin. Data from the trap at GCID and other downstream locations may be of particular importance.

2). Consider use of Balls Ferry screw trap data when looking at survival of winter Chinook from the spawning ground to the Delta.

3). Continue analysis of egg to smolt survival, with special regard to the usefulness of the data from the Tehama-Colusa Fish Facility.

4). Gather more information on the behavior of juvenile winter Chinook.

5). Continue to expand on the use of system, life cycle and cohort approaches to looking at such important issues as production, and the impacts and benefits of EWA and other actions.

Forecasting Juvenile Production

Michael Mohr, of NMFS, stood in for Steve Lindley by making the presentation on forecasting juvenile winter Chinook production. The presentation is an update of the material summarized in the 2001 salmonid workshop.

The NFMS staff at Santa Cruz is working with Ken Newman of the University of Idaho to develop a State Model that can overcome some of the shortcomings of the current estimate of the JPE. Their overall goal is to obtain more accurate and precise estimates of juvenile abundance. Another goal is to use a variety of data sets to estimate not only adult abundance, but the age composition of the adult population. The resulting information can be used to make more informed take limits and also to better manage the entire winter Chinook recovery process.

Some ideas for improving the JPE include:

1). The more data the better, for example

   a). RBDD counts;

   b). carcass mark-recapture studies;

   c). aerial redd surveys;

   d). estimates of juvenile abundance at different locations in the system; and

   e). age structure.

2). Recognize uncertainty and deal with it.

3). Use structural time series models that

   a). are based on winter Chinook life cycle;

   b). incorporate biological variation;

   c). incorporate measurement variation;

   d). assimilate multiple observation series;

   e). classify individuals by state components of age, sex, and maturity;

   f). are not a series of black boxes;

   g). include updating and prediction steps; and

   h). take into account cohort progression from time t to time $t + x$ years.

The modelers are now working on simulation studies to examine the effects of the length of the different time series, the precision of the observations and observation scale—fine or coarse—(in fine scale adults are aged and sexed and in coarse scale they are only sexed) on abundance estimates and survival probabilities.

Currently Newman and Lindley are working to develop a simplified model for application to total escapement data and apply the simple model to real data. They intend to publish at least two papers from this work, the first on the estimation procedure for generalized structural time series models and another on the on the application of these models to winter Chinook.

A Comparison of Juvenile Emigration in 2000–2001 and 2001–2002

Jim White (DFG) presented information about spawner estimates, salmon catches upstream of the Delta, environmental variables, pumping and salmon take at the pumps to examine the general question, "Why was winter Chinook take in 2000-2001 so much higher than in 2001-2002?"

Jim's approach to answering the question is based on looking at spawning stock estimates and the catches at several points down the river and at the exit point from the Delta, Chipps Island. Under this qualitative approach, the location where mortality may have occurred can perhaps be established, however the exact causes of the mortality are not yet possible to sort out.

- *Estimated escapement.* Using carcass survey data from both years, the estimated number of females in the 2000 broodyear was 3551 and 4876 for the 2001 broodyear - a 37% percent increase.

- *Upper river RSTs*. Jim did not look at the data from the Balls Ferry rotary screw trap (above Red Bluff) and RSTs at the RBDD were not operated in 2001 or 2002. (These funding problems have now been resolved.)
- *Mid-river RST*. DFG operates a RST in the intake channel to the Glenn-Colusa Irrigation District's (GCID) diversion near Hamilton City. Peak in winter run catch from the 2000 and 2001 broodyears was typical of most years, although the peak for 2001 was lower than observed for 2000. Trap efficiency has not been estimated at GCID so population estimates can not be calculated.
- *Lower River RST*. DFG operates a RST in the Sacramento River near Knights Landing. The data from the two broodyears (Figure 7) show that migration patterns differed in the two years - with the 2000 broodyear juveniles moving past Knights Landing much later than those from the 2001 broodyear. Preliminary estimates are that about 100,000 juvenile Chinook salmon in the winter run size range from the 2000 broodyear migrated past Knights Landing, (80% CI is 38,000 to 98,000), whereas there were only about 61,000 from the 2001 BY (80% CI is 57,390 to 81,015).

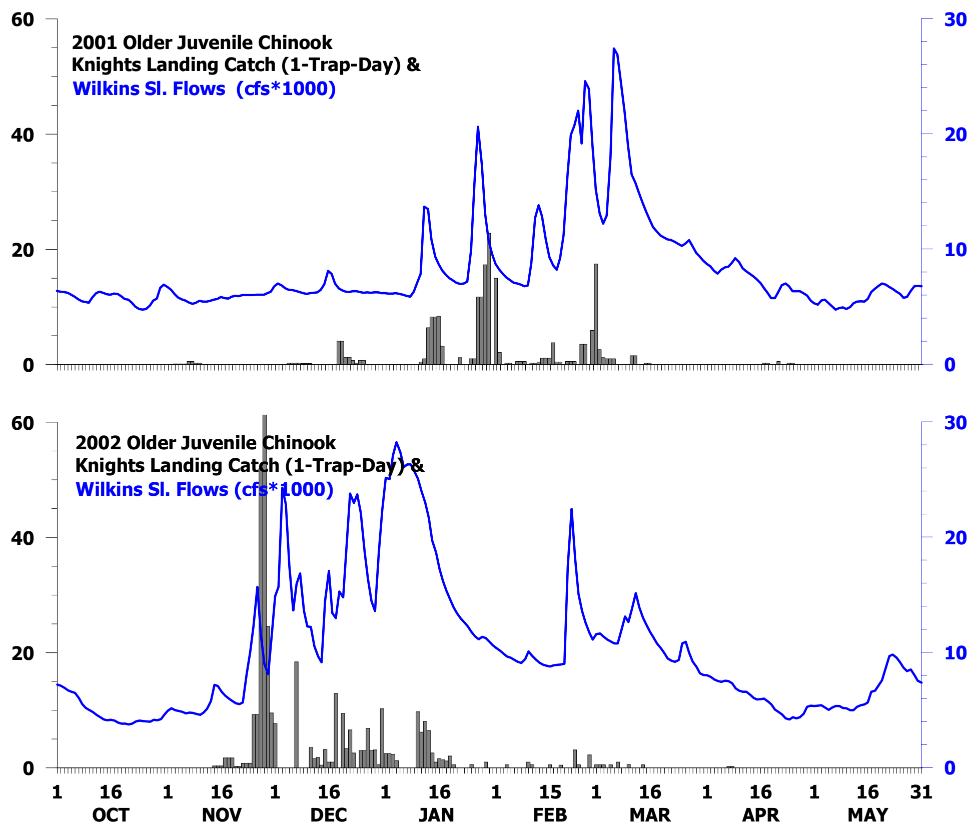


Figure 7 Catches of older juvenile Chinook salmon by rotary screw traps at Knights Landing on the Sacramento River, 2001 and 2002. Data: Bill Snider, DFG. Plots: Jim White, DFG.

- *Catch at Chipps Island*. The expanded juvenile winter Chinook catch at Chipps Island for BY 2000 was about 181,000 as compared to about 36,000 for BY 2001. It should be noted that BY 2001 only includes data through March. Although the complete estimate was not available, the April/May data were not expected to change the conclusion that fewer juvenile winter Chinook reached in Chipps Island in the winter/spring period of 2001-2002 as compared to the same period in 2000-2001. (Subsequent to the workshop, the USFWS provided an estimate of the winter Chinook passing Chipps Island from BY 2001 based on catch data from the full emigration season - 138,430. This is a much larger difference between the February/March estimate and the full season estimate than observed in previous years and may suggest a departure in 2002 from the presumed "typical" migration timing which has most juvenile winter Chinook migrating from the Delta in February and March.)

To complete the picture, calculated take at the pumps was 19,848 for BY 2000 and 3,330 for BY 2001. The distinctly different take patterns for the two years is illustrated in Figure 8.

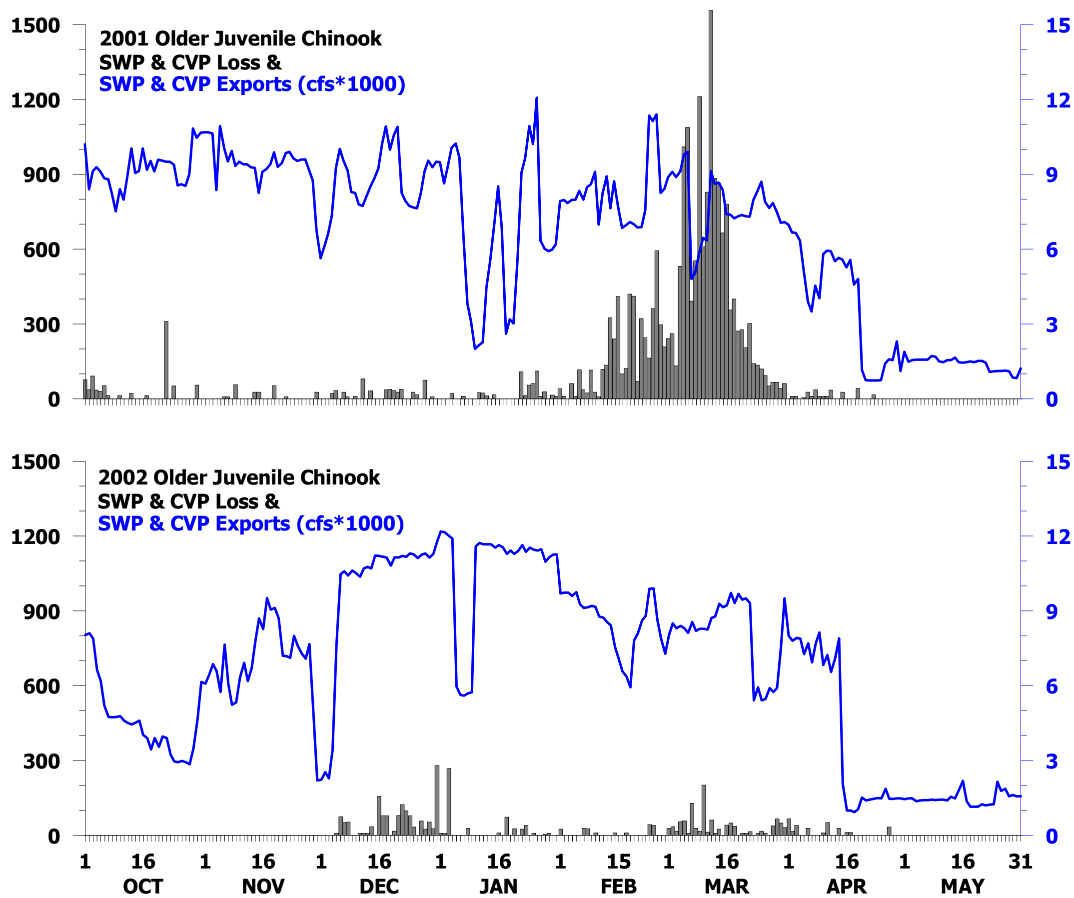


Figure 8 Losses of older juvenile Chinook at the state and federal intakes and total pumping, 2001 and 2002. Source: Jim White, DFG.

Jim summarized the above with the following points: (Note that the calculated percentages use the point estimates and do not include any error bars. As such the estimates are used in a qualitative sense.)

1). BY 2001 had 37% more winter Chinook females than BY 2000.

2). Yet only about 60% as many BY 2001 juvenile winter Chinook were estimated to have passed Knights Landing compared to BY 2000.

3). And on about 20% as many BY 2001 juvenile winter Chinook reached Chipps Island compared to BY 2000 (about 50% as many BY 2001 as BY2000 using estimates based on expanded full season catch data).

4). Calculated take of BY 2001 juvenile winter Chinook was only 17% of that from BY 2000.

A partial annotated list of the possible explanations for an apparently larger BY 2001 spawning population producing fewer progeny surviving to the Delta includes:

- High early mortality in the egg or fry stage perhaps due to high water temperatures. This was ruled out because Shasta Reservoir temperature management provided safe water temperature for eggs and fry.
- Spills from the Spring Creek debris dam causing toxicity problems. This was ruled out - Spring Creek Debris Dam spills were managed successfully and harmful concentrations of potentially toxic elements were avoided.
- Other water quality problems.
- Juveniles took alternate migration routes during the two years. Some winter Chinook passed over weirs into the Sutter Bypass (possible on about 10 days in January 2002) and were not subject to capture at Knights Landing. Others could have passed Knights Landing and then used the Yolo Bypass (possible on about 7 days in January 2002) to migrate to the Delta. Evidence suggests these bypasses provide good rearing habitat for juvenile Chinook, however the brief period of inundation (days) may have been an unfavorable scenario compared to prolonged bypass flooding (weeks or even months).
- The effects of river flow magnitude and timing. There was more fall and winter flow, but lower spring flow in 2002 than 2001. These differences in hydrology between years appear to have affected the timing and extent of downstream dispersal and migration of juvenile Chinook and possibly affected their survival.
- Pumping rates. The rates were quite different at times in the two years. When there were differences, export pumping was generally higher in December - March 2002 than in 2001, whereas winter Chinook take was much higher in 2001.
- Delta Cross Channel gate operations. For BY 2000, closed only about one-third of the time in December 2000 and January 2001, then closed February through late May, compared to closed in early December 2001 through the remainder of the winter and spring of 2002 for BY2001.

A general conclusion was that more quantitative analysis needs to be done on the data sets to see if the causes of the differences can be teased out. Additional staff is needed to help in these analyses and field sampling may need to be augmented.

A Hypothesis to Explain Annual Variability of Winter Chinook Take at the Pumps

Alice Low (DFG) presented an hypothesis that the percentage of Sacramento River flow that enters the interior Delta by way of the Delta Cross Channel (DCC) and Georgiana Slough is an important predictor for subsequent losses of winter Chinook at the state and federal Delta facilities. The hypothesis came, in part, from the observed high interannual variation in winter Chinook take at the pumps (Figure 9). Accepting this hypothesis may also modify our conceptual model of the use of the Sacramento-San Joaquin Delta by juvenile winter Chinook.

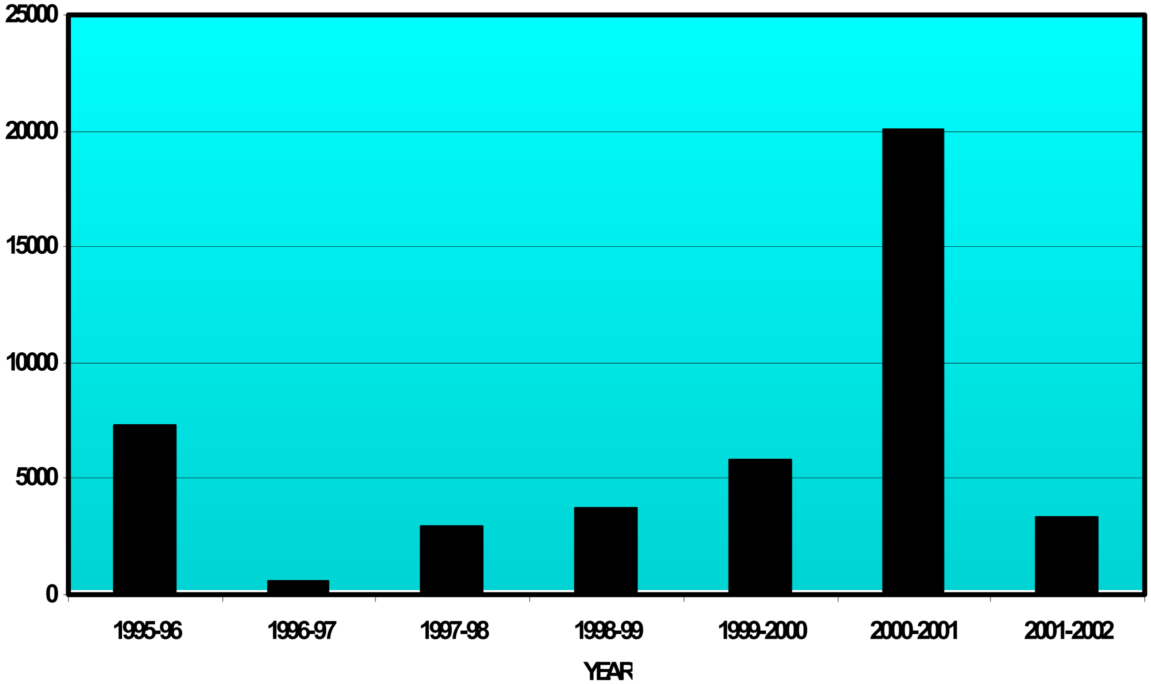


Figure 9 Estimated total annual losses of juvenile Chinook salmon at the state and federal Delta facilities, 1995–1996 through 2001–2002. Source: Alice Low, DFG.

Alice explored the hypothesis by looking at movement of juvenile winter Chinook down the Sacramento River and into the Delta to determine when the juveniles would be vulnerable to entrainment into the interior Delta through the DCC and Georgiana Slough (and the pumps) and then estimating the proportion of the Sacramento River flow entering the interior Delta during this period. In the final step, simple linear regression was used to determine if total take at the pumps during the season is related to the estimated proportion of Sacramento River during the period of juvenile winter Chinook emigration through the lower Sacramento River.

Starting upstream, it appears that peak timing of juvenile winter Chinook past Red Bluff Diversion Dam is rather consistent, typically occurring in September (as indicated by expanded rotary screw trap catches, Figure 10). The relative magnitude of catches, however, is quite variable. Downstream of Knights Landing, (RM 89.5) additional RST sampling indicates that timing of and catch magnitude is more variable (Figure 11). Here it appears in most years peak winter Chinook emigration past Knights Landing occurs between late November and mid-December. Catches from beach seine sampling in the lower Sacramento River (Figure 12) also indicate that, in most years, most of the winter Chinook juveniles reach the lower Sacramento River from late November through late December.

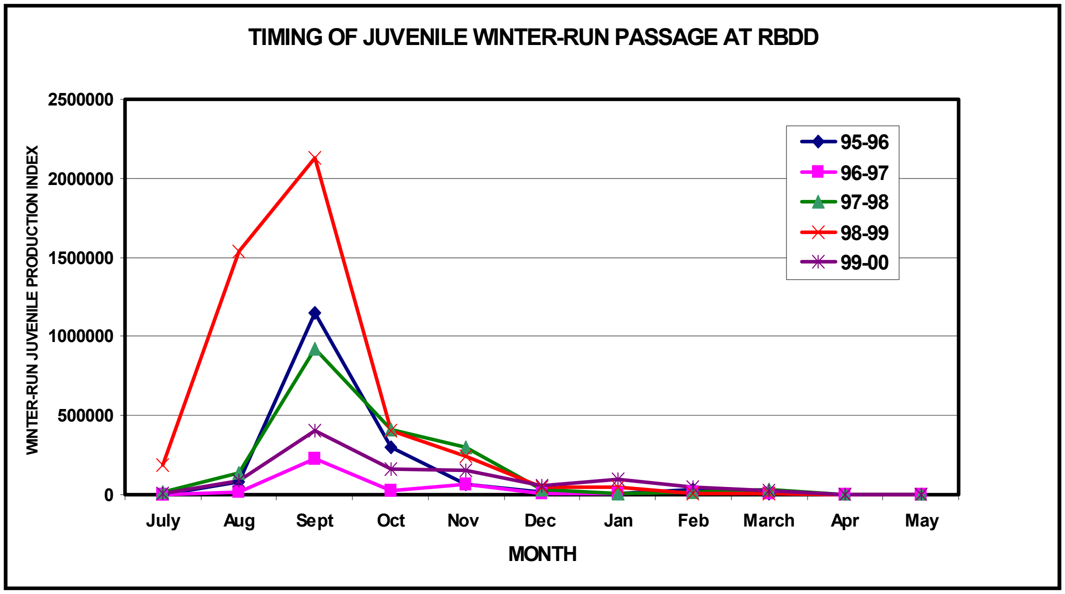


Figure 10 Seasonal timing of juvenile winter Chinook movement past Red Bluff Diversion Dam as estimated from rotary screw trap catches. Source: Alice Low, DFG.

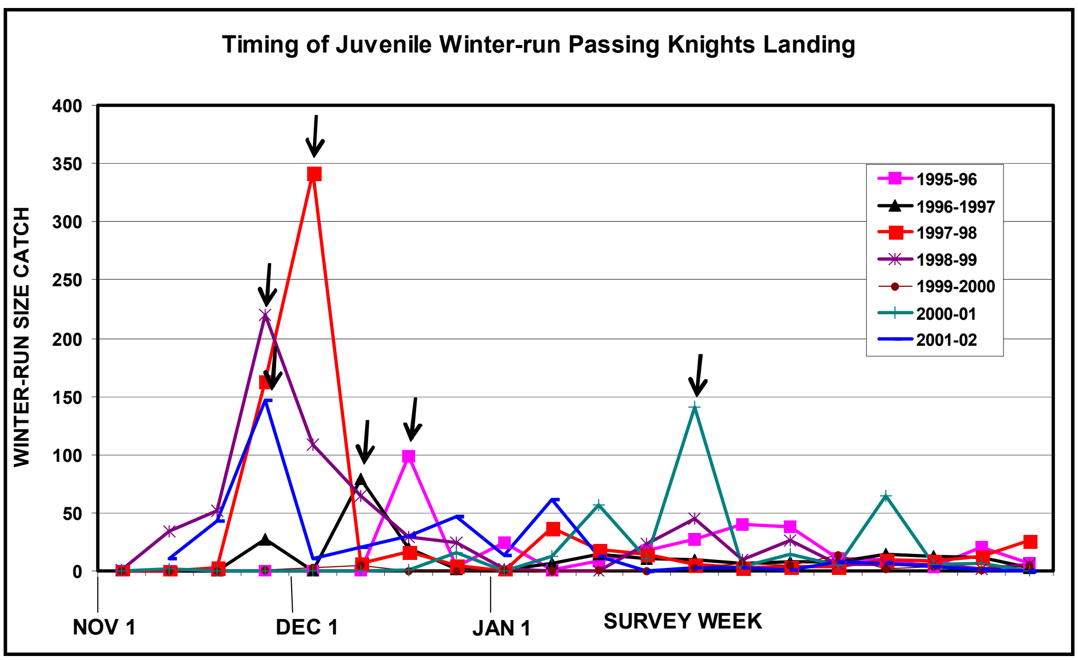


Figure 11 Seasonal timing of juvenile winter Chinook movement past Knights Landing as estimated by rotary screw trap catches. Source: Alice Low, DFG.

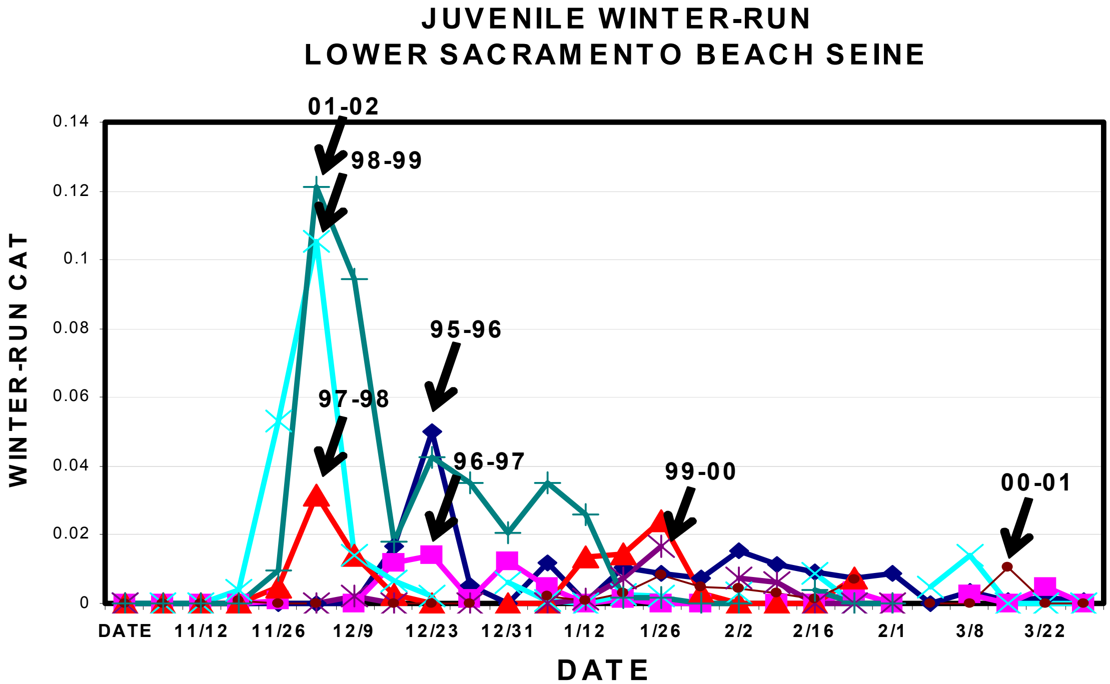


Figure 12 Monthly catches of juvenile winter Chinook in lower Sacramento River beach seine hauls. Source: Alice Low, DFG.

Alice next plotted combined take at the Delta facilities and catch at Knights Landing over time for the past five winter Chinook emigration periods (Figure 13, plates 1-5). Peak losses at the pumps occurs from 1 to 4 months after peak passage at Knights Landing. This is evidence that these fish were rearing in the Delta for significant periods before actively emigrating from the system.

Plotting the annual take of winter Chinook versus flow through the DCC and Georgiana Slough into the interior Delta for the November through January period was the final step in the analysis. Using seven years of data, Alice found the relationship for the month of December was positive and significant but relationships for November and January were not significant (Figure 14). A further breakdown of the emigration period (Figure 15) indicated the critical period may be the first two weeks of December.

Alice elaborated some possible implications of her analysis.

- Juvenile winter Chinook emigrating through the lower Sacramento River in December may enter the interior Delta in proportion to flow through the Delta Cross Channel and Georgiana Slough.
- A portion of the winter Chinook populateion in the interior Delta may rear there and be vulnerable to loss at the Delta facilities in later months.
- EWA assests might be better used for winter Chinook protectin by keeping juveniles from the interior Delta in the winter, rather than making later sprint curtailments.

Alice also had the following suggestions for additional research.

- Further analyze existing monitoring data. (In two years, winter-run juveniles were not observed in significant numbers in the lower Sacramento River in December.)
- Improve monitoring juvenile winter-run emigrating down the Sacramento River.

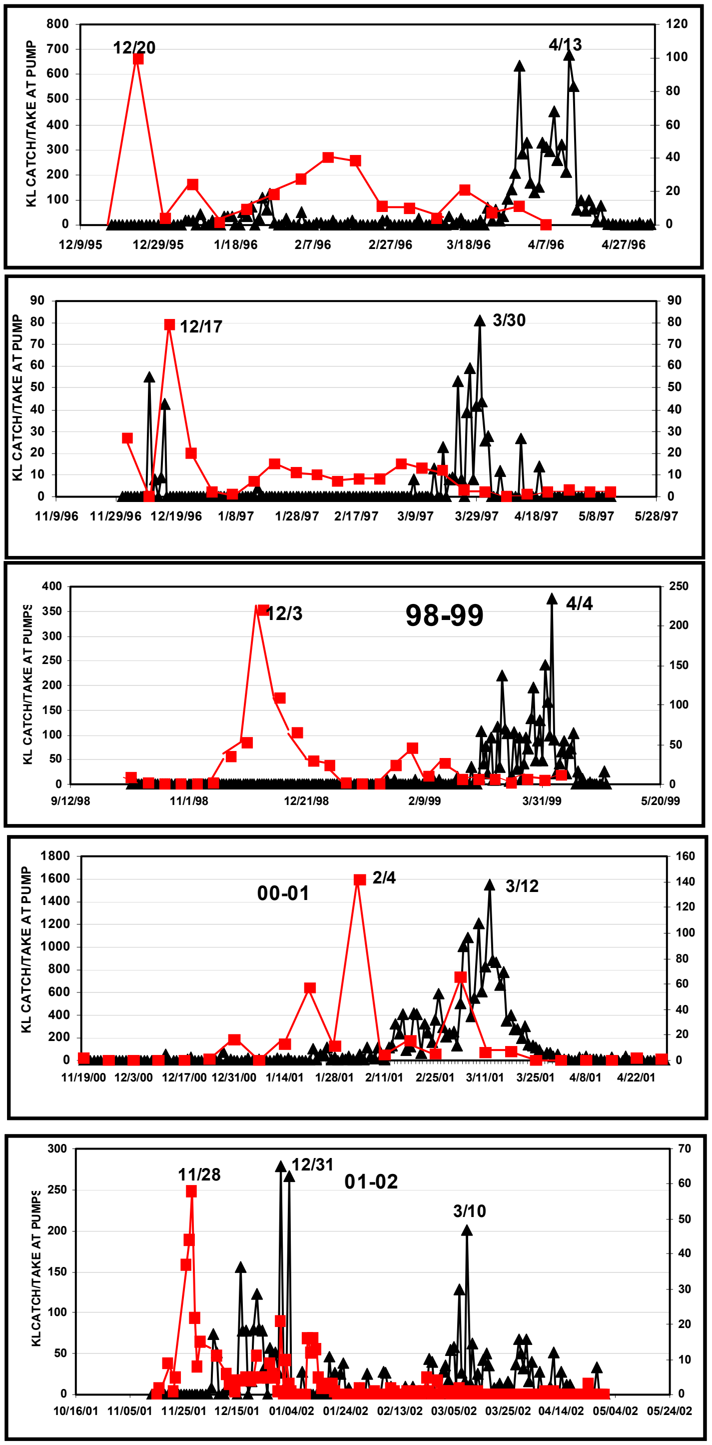


Figure 13 Catches of juvenile winter Chinook in Knights Landing rotary screw traps and take at the project pumps in the south Delta, 1995-1996 through 2001-2002. Source: Alice Low, DFG.

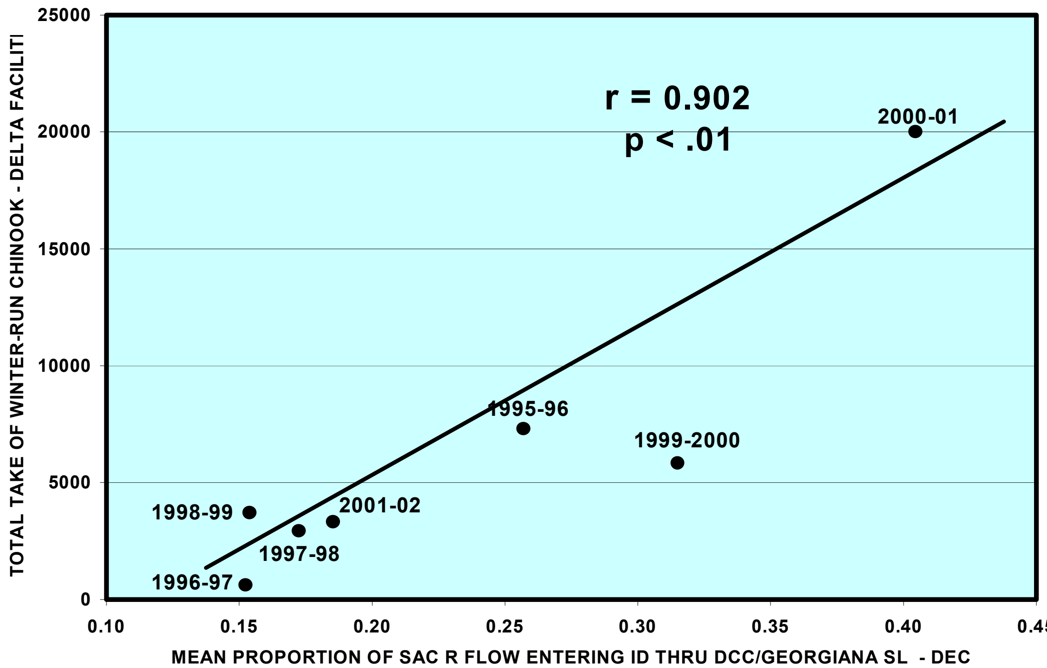


Figure 14 Relation between estimated proportion of water entering the interior Delta from the Sacramento River and estimated take of juvenile winter Chinook at the pumps during the month of December, 1996–1997 through 2001–2002. Source: Alice Low, DFG.

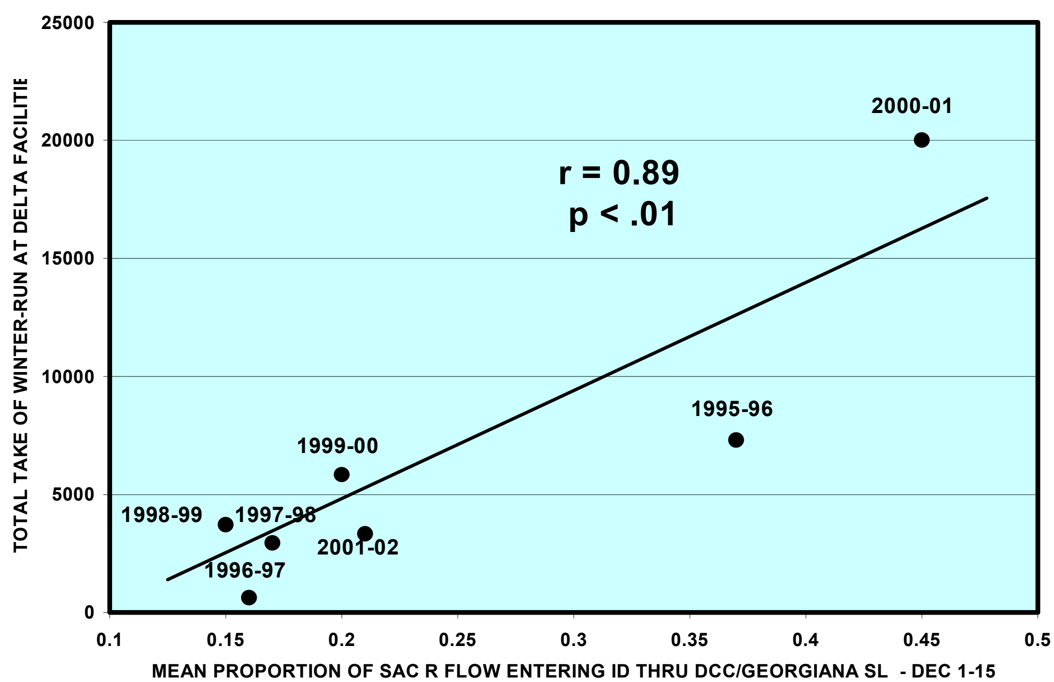


Figure 15 Relation between estimated proportion of water entering the interior Delta from the Sacramento River and estimated take of juvenile winter Chinook at the pumps during the period December 1-15, 1996–1997 through 2001–2002. Source: Alice Low, DFG.

Delta Action 8 Refinements—How Factors and Assumptions Affect the Benefits Estimated from Export Curtailments on Juvenile Salmon Survival

Pat Brandes of the USFWS (Stockton) presented information to increase our understanding of the effects of pumping curtailment on survival of emigrating Chinook salmon. The results discussed were based primarily on Delta Action 8, a series of studies that uses mark recapture techniques to compare the survival of marked juvenile Chinook salmon released into the interior Delta (Georgiana Slough) with survival of similar groups released in the Sacramento River downstream of the Georgiana Slough/Delta Cross Channel complex (see Figure 16) for release sites). These fall/winter studies have been conducted over the past 9 years using marked (coded wire tags and adipose fin clips) late fall Chinook obtained from the Coleman National Fish Hatchery. Survival to Chipps Island is indexed from the recapture of marked fish in s mid-water trawl. Additional survival indices can be computed from the recovery (and reading) of tags collected in the ocean recreational and commercial salmon fisheries. Recovery of the tagged fish at the state and federal fish protection facilities also provides an indication of the fate of the released fish. A more thorough description of the methods can be found in Brandes and McLain (2001).

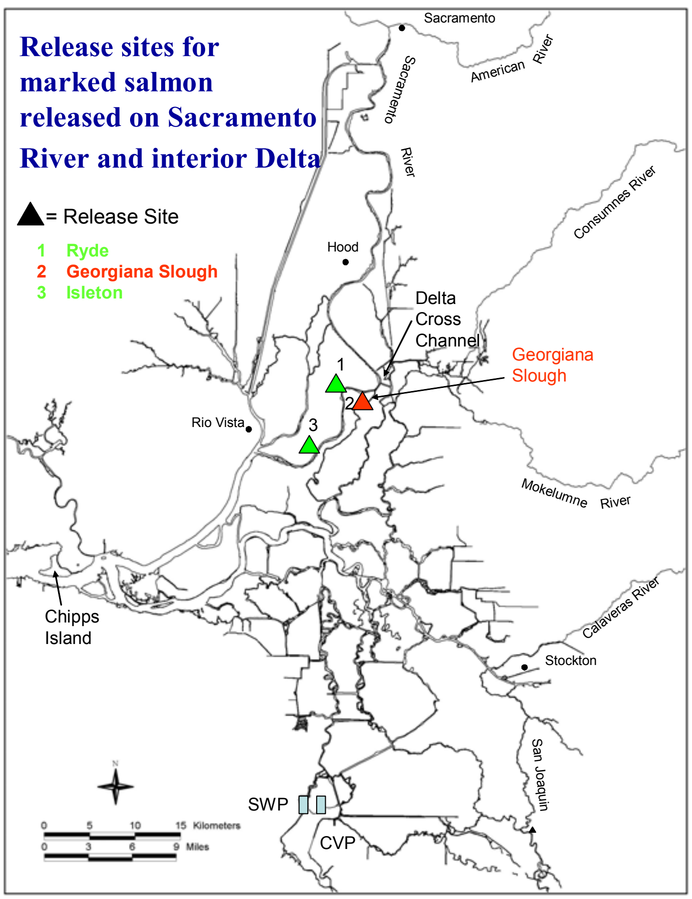


Figure 16 Release sites for marked juvenile late-fall Chinook released as part of Delta Action 8 studies. Source: Pat Brandes, USFWS.

As shown in Figure 17, survival indices of marked Chinook salmon released at Ryde/Isleton (on the Sacramento River downstream of Georgiana Slough) have always been higher than survival indices of fish released in Georgiana Slough. Although the flow into Georgiana Slough is not related to project pumping, one explanation for the difference in survival is that fish entering Georgiana Slough (or the interior Delta for that matter) have a longer path to Chipps Island and may be exposed to the effects of project pumping when they exit the Slough. As shown later in this report (page 37), radio tagging studies indicate that juvenile salmon may be particularly vulnerable to predators in the upper reaches of the Slough.

The potential effects of project pumping were then explored by plotting the Georgiana Slough/ Ryde ratio of survival against mean total CVP and SWP exports for 3 and 17 days after the fish had been released (Figure 18). The survival/3-day export relationship is shown in Figure 19, along with the confidence intervals. In general it appears that fish released into Georgiana Slough are most susceptible to effects of project pumping when combined pumping reached levels on the order of 10,000 cfs and that use of three days of post release pumping is more useful than 17 days post release data.

Survival ratios using both the Chipps Island and ocean tag recovery data are plotted against 3-day exports in Figure 19. Note that there is two-year or so delay in recovering tags from the ocean fisheries as compared to Chipps Island. The ocean recovery information does not change the general conclusion one would reach from the experiments.

Figure 20 shows tracking data from radio tagged fish released in Georgiana Slough indicating that the fish move down the slough and do not reverse course and enter the Sacramento River. This movement is consistent with the observation that net water flow in Georgiana Slough is unidirectional - towards the lower San Joaquin River (Dave Vogel, personal communication). Ecologically this indicates that once fish enter Georgiana Slough (for whatever reason) they will have to travel a fairly circuitous route to Chipps Island and their chances of making it are less than if they had remained in the mainstem Sacramento River.

The experiments clearly demonstrate that juvenile Chinook salmon entering the interior Delta have a lessened chance of reaching Chipps Island, and ultimately the ocean. Although not as clear, at combined exports of around 10,000 cfs and above, pumping adversely affects survival of fish that are in the interior Delta. The benefits of pumping curtailment on the total population of Sacramento basin Chinook salmon smolts moving through the Delta (the assumption being that the smolts are actively migrating), are affected by the percentage of those fish that enter Georgiana Slough, the original pumping level and the extent of curtailment. Pat simulated the effects of the various combinations of variables to estimate their effects in Table 5.

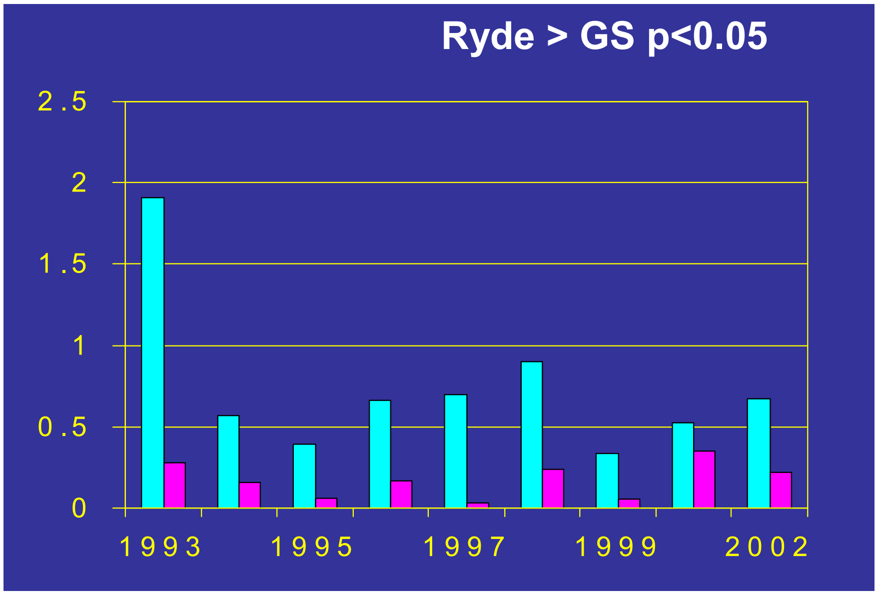


Figure 17 Survival indices to Chipps Island of marked late-fall juvenile Chinook salmon released on the Sacramento River and in Georgiana Slough, 1993-2002. Source: Pat Brandes, USFWS.

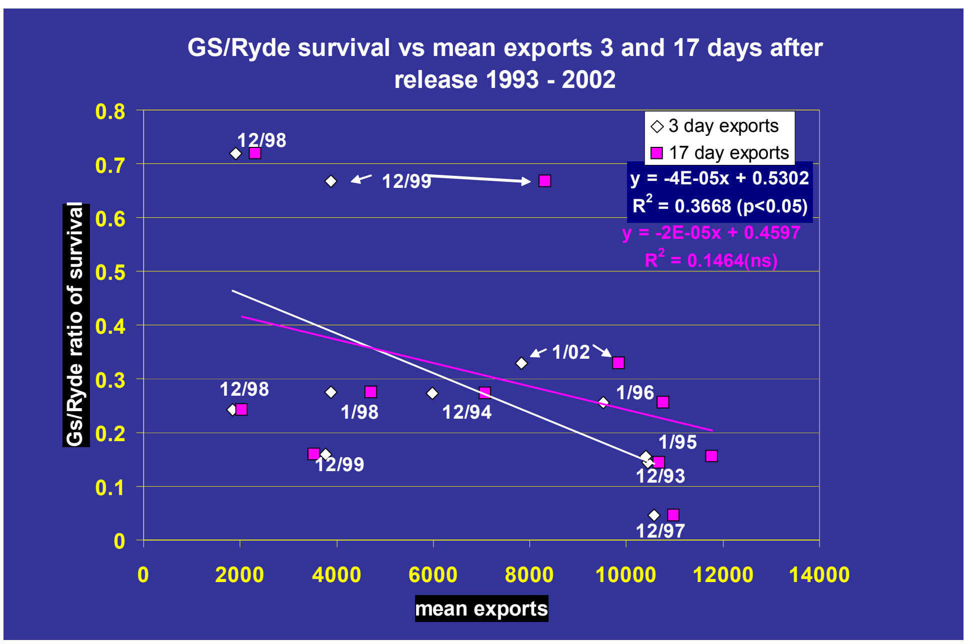


Figure 18 Plot of the ratio of Georgiana Slough/Ryde survival indices to Chipps Island and average exports for 3 and 17 days after release of marked juvenile late-fall Chinook, 1993–2002. Source: Pat Brandes, USFWS.

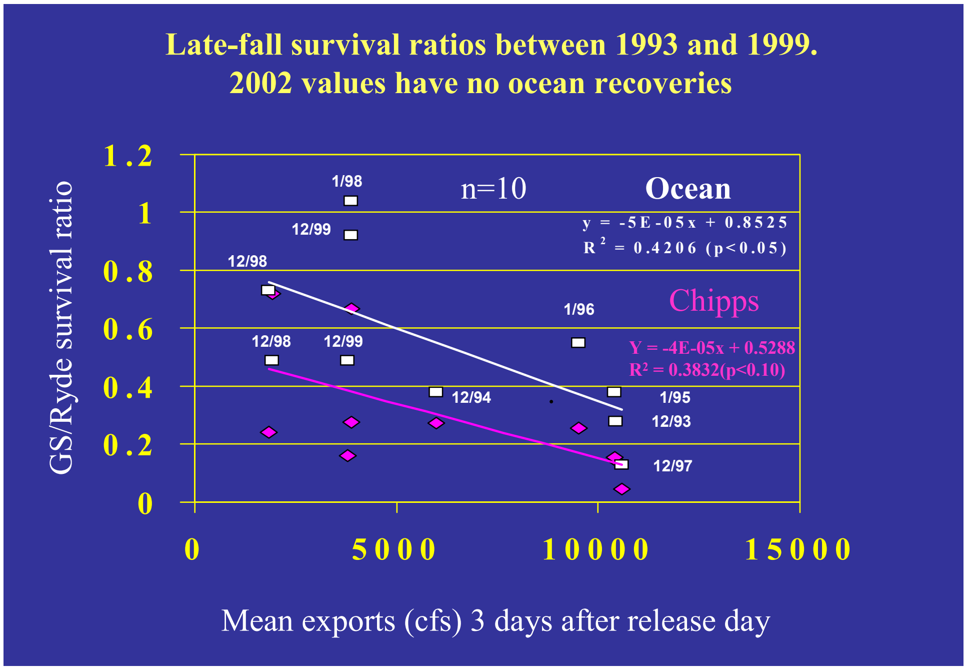


Figure 19 Plots of late-fall Chinook survival indices to Chipps Island and the ocean fishery versus average exports for three days following release of marked salmon, 199-1999. Source: Pat Brandes, USFWS.

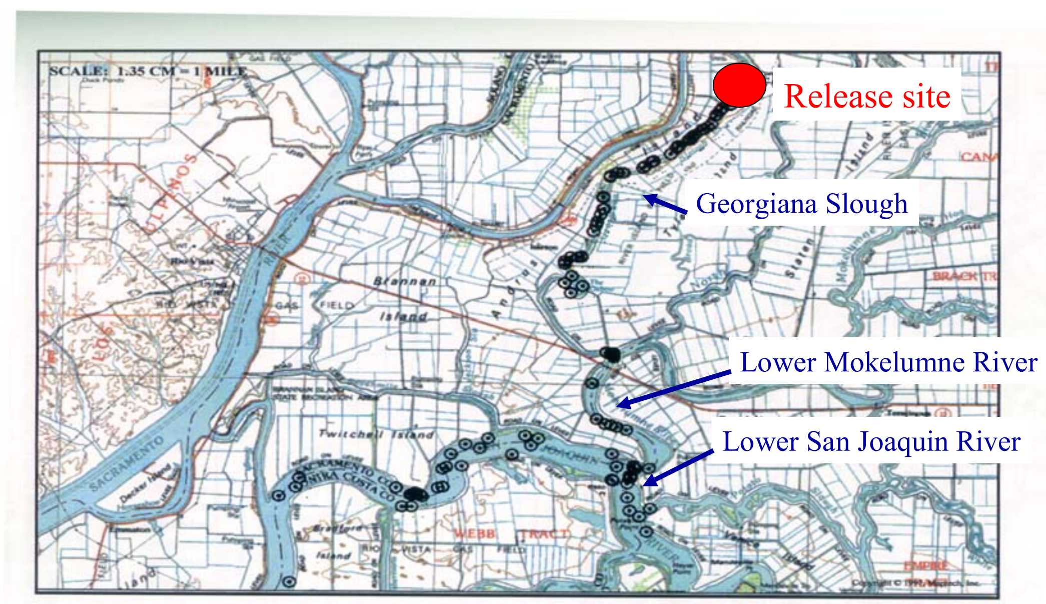


Figure 20 Movement of radio tagged juvenile late-fall Chinook as indicated by detections for up to three days after release. Source: Dave Vogel, NRS, Inc.

Table 5 Benefits to survival of export curtailments affected by percent diverted into the interior Delta

Exports	*GS/ Ryde Ratio*	*Ryde Survival*	*Percent in Mainstem*	*Interior Delta Survival*	*Percent in Interior Delta*	*Interior Delta Population Affected*	*Total Delta Survival*	*Improve -ment (%)*
10000	0.13	0.80	0	0.10	100		0.10	
6000	0.29	0.80	0	0.23	100	100	0.23	123
10000	0.13	0.80	55	0.10	45	100	0.49	
6000	0.29	0.80	55	0.23	45	100	0.54	12
10000	0.13	0.80	82	0.10	18		0.67	
6000	0.29	0.80	82	0.23	18	100	0.70	3
10000	0.13	0.80	55	0.10	45		0.49	
6000	0.29	0.80	55	0.23	45	100	0.54	12
10000	0.13	0.80	55	0.10	45		0.49	
6000	0.29	0.80	55	0.23	45	25	0.54	3
10000	0.13	0.80	55	0.10	45		0.49	
6000	0.29	0.80	55	0.23	45	25	0.54	3
11000	0.09	0.80	55	0.07	45		0.47	
2000	0.45	0.80	55	0.36	45	25	0.60	7

Discussion of Indirect Mortality in the Delta

Although we continue to gather more valuable information, there is still considerable uncertainty about the factors that control the survival of juvenile Chinook salmon rearing in or migrating through the Delta. (Note that the workshop focused on Sacramento basin emigrants and little attention was given to emigrants from the San Joaquin basin and such eastside streams as the Mokelumne and Cosumnes rivers.) Some of the areas of increased understanding and remaining uncertainty are:

Evidence continues to mount that movement of juvenile salmon from the Sacramento reduces survival. Cross channel gates closures can improve survival but recent studies have confirmed earlier work showing that Georgiana Slough is an important pathway to the interior Delta - even more important that simple flow splits would indicate. Additional studies over a wider range of flows are needed to demonstrate the importance of this path over the range of flows seen during the critical winter emigration period.

The importance of the Delta as rearing habitat is still uncertain. Low (page 26) hypothesizes that the winter Chinook take at the pumps is tied to the numbers of juveniles entering the Delta in early December, indicating Delta rearing.

The causal mechanisms for the observed indirect mortalities such as reduction in survival when the cross channel gates are open or pumping is at the higher range.

What is percent of downstream migrating fish entering the interior Delta (fraction of total population) and how does this percentage vary over a range of flows and other environmental conditions?

There was some interest in developing conceptual models of smolt movement and survival in the Delta.

Studies of Juvenile Salmon Movement in the Delta Using Radio Tags

The following is drawn from a workshop presentation by Dave Vogel of Natural Resource Scientists, Inc. (NRSI) and from Vogel (2001, 2002). To help understand the results we have included some background material on study methods not presented at the workshop.

As shown in Table 6, the radio tagging studies in the Delta using juvenile salmonids began in 1996–1997 in the lower Mokelumne River. Since then, NRSI has conducted an additional six studies in various parts of the Delta.

Table 6 Radio tagging juvenile salmon studies conducted in the Delta, 1996–2002

Season	*Year*	*Location*	*Sponsor*
Spring/Fall	1996–1997	Mokelumne River	EBMUD
Winter	1999–2000	North Delta	USFWS
Fall	2000	Delta Cross Channel	CALFED
Winter	2000–2001	South Delta	USFWS
Fall	2001	Delta Cross Channel	CALFED
Winter	2001–2002	North Delta	USFWS
Spring	2002	Central Delta	CALFED

The short term studies were designed to help determine how individual juvenile Chinook salmon respond to various hydrodynamic conditions in the Delta, to different pumping levels at the state and federal water projects in the south Delta, and to flow splits at prominent physical features in the Delta. The studies were short term because dispersion of the released fish and short battery life limited tracking the fish to a maximum of four days post release. Tracking the fish also allowed the researchers to gain insight in rate of movement, location of fish in the channels (high or low in the water column and horizontal location) and the location of areas in the Delta that appeared to be predation hot spots.

The following brief description of the study methods is taken from Vogel (2001).

Study fish. NRSI obtained late fall Chinook from the Coleman National Fish for all the radio tagging studies. Hatchery. Typically 10 to 15 radio tagged fish were used in each release group. Fork length of the study fish ranged from about 150 to more than 200 mm. with the average size usually in 170 mm range. All test fish were coded wire tagged and adipose clipped at the hatchery. Each release group included 10 to 20 coded wire tagged "escort" fish, the idea being that the larger number of fish might promote more natural schooling of the released fish.

Transmitter. The transmitter was approximately 6x16mm, weighed about one gram and had a 25 cm antenna. NRSI used an external tag harness, with wires running through the dorsal musculature, to attach the transmitter to a fish.

"Attachment" controls. In all experiments the researchers used the same experimental protocols to attach dummy transmitters to 3 to 5 late fall Chinook. The attachment controls were held for approximately the length of the study to assess any latent mortality due to attaching the transmitter. In essentially all cases latent mortality was zero.

Tracking tagged fish. Fish movement was followed for 3-4 days after release by use of radio scanning receivers mounted on a jet boat. Due to safety concerns, the boat was only operated for 10-11 hours during the daylight hours. Early studies had attempted to use a pickup mounted scanner but this was found not be feasible due to safety concerns on the narrow levee roads and the inability to get close enough to the tagged fish. The scanners would run through the range of frequencies being used and when the observers detected a tagged fish, they recorded: time, location (using GPS), relative location in the channel and apparent flow direction in the channel. In those studies in the south Delta, the researchers attempted to use a fixed scanner and data logger near the entrance to Clifton Court Forebay but background noise and other factors caused the data to be unusable.

Ancillary data. On the first day of some of the tests, a USGS employee used an ADCP to determine flow direction, velocity and depth. Data from fixed UVM stations were also used when appropriate.

Study limitations. The use of hatchery fish, the presence of rather large external tags (including the antenna), the large size of the test fish (compared to emigrating smolts, the relatively short battery life, and artificial nature of the tagging and release process limit applying study results to the movement and fate of juvenile salmon moving through the Delta. In spite of these limitations, radio tagging technology does provide a means of tracking individual salmon as they move and react to changes in flow and channel junctions.

In the presentation, Dave used time lapse to illustrate movement of tagged fish through the Delta channels - a technique not as effective in a summary report. We chose instead to focus on some general conclusions and recommendations from the studies, and include some data.

1). *Fish movement.* Tracking individual salmon after release indicated some interesting patterns. There was wide movement and rapid dispersal of fish after release and the fish did not move in schools. Although there was some variation, during daylight tracking hours the fish seemed to move mostly in mid-channel. The tagged fish generally moved back and forth with the tides and did not hold position on flooding tides. Flow measurements and fish movements indicated that the fish appeared to be moving slightly slower than the flow (Figure 21). The short battery life and the wide dispersal of test fish limited the ability to determine how the fish actually exited the Delta.

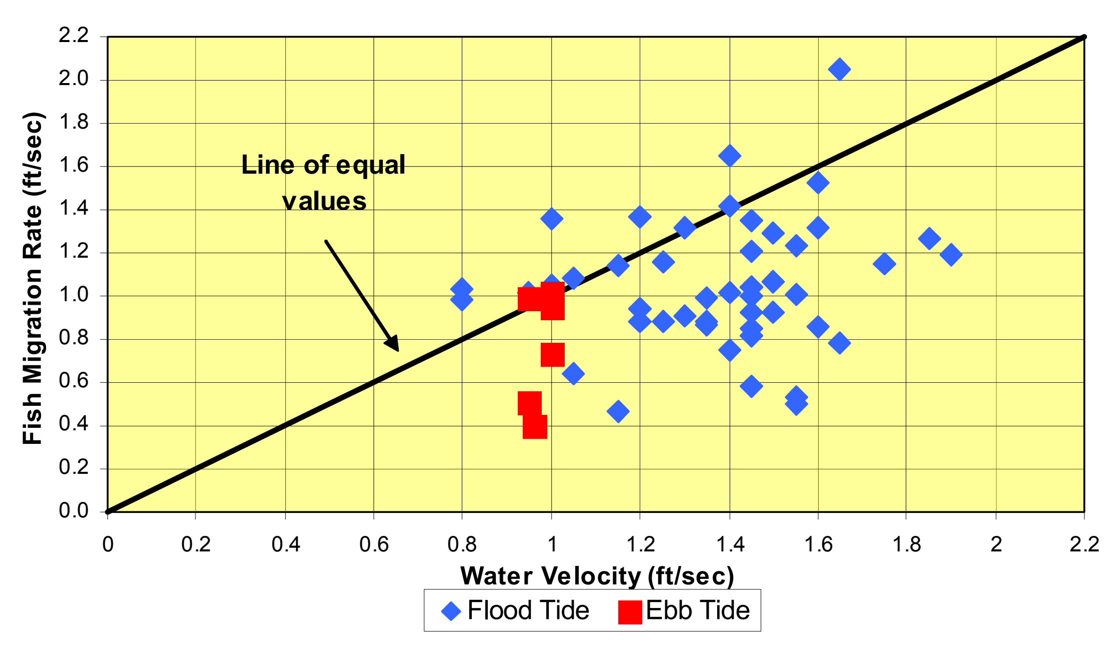


Figure 21 Comparison of fish migration rates as estimated by movement of radio tagged fish and estimated ambient water velocities. Source: Dave Vogel, NRC, Inc.

2). *Predation.* After following hundreds of tagged fish during the seven radio tagging studies the field crews developed a sense of where the tagged fish were being taken by fish or avian predators. The observations, although somewhat limited in geographic extent, indicated that the upper reaches of Georgiana Slough and the lower Mokelumne River may be areas where significant losses to predators occur. On the other hand, predation in the Delta portion of the mainstem Sacramento seemed to be minimal.

3). *Losses to Project diversions in the south Delta.* In December 2000 and January 2001, NRSI released a total of 50 radio tagged late fall salmon in four groups in lower Old River near Woodward Island - close to the south Delta diversions. (Table 7 illustrates the numbers of tagged fish along with the numbers of "escort fish" used in the three tests.) Two release groups were during medium export levels (combined exports of 8,000 to 10,000 cfs) and two at low exports (combined exports of 2,000 to 5,000 cfs). The results of these experiments (Table 7) indicate that fish released near the intakes have a high likelihood of being entrained into project intakes when pumping is in the range of 8,000 to 10,000 cfs range. It should be noted that radio tagged fish were not recovered in the salvage facilities nor were they tracked going into the facilities. The entrainment losses were estimated from observations of movement patterns. For example, fish released at the medium pumping rates generally moved due south towards the facilities, whereas fish released during low exports tended to move north. Although no radio tagged fish were recovered at the facilities, four escort fish were recovered: three at the SWP and one at the CVP.

Table 7 Results of south Delta experiments—hypothesized fate of released fish

Experiment	*1*	*2*	*3*	*4*
Export	Medium	Medium	Low	Low
Entrainment	8 (62%)	8 (67%)	3 (23%)	4 (33%)
Predation	2 (15%)	3 (25%)	1 (8%)	0 (0%)
Within Delta or Unknown	3 (23%)	1 (8%)	9 (69%)	8 (67%)

4). *Continued use of radio tagged fish in Delta studies.* The information has proved useful and the radio tag application procedures can be handled without apparent undue stress, and no short-term morality. It thus appears that radio tagging is a useful tool to be included in Delta salmonid studies.

5). *Recommendations for additional studies.* As with most experimental studies, the results, and their interpretation lead to the need for additional studies. A few of these recommended by NRSI are:

a). Compare behavior between fish with internal and external radio tags.

b). Compare behavior between tagged hatchery and wild fish.

c). When working in the south Delta, station an observer near the intake to Clifton Court Forebay.

d). Follow movement at night, perhaps by use of on-board radar to detect hazards.

Comments from the EWA Science Advisors

The 2002 Salmonid Workshop

Overall the workshop provided a good opportunity for agency biologists (and one outsider) to present information relevant to the use of EWA for protecting Chinook salmon. There was also ample opportunity for discussion, and an atmosphere conducive to dialog. We commend the organizers of this workshop for this positive outcome.

We were particularly interested in the discussions of confidence limits, and in recent analyses done to extend our understanding using existing data. Jim White's analysis and Pat Brandes' presentation suggested a more substantial loss to export pumping than we had previously considered.

If that is accurate, it puts the EWA in a new light; thus, we believe this is a very important avenue for further statistical analyses and review of these analyses.

We were also pleased by the changes in the JPE—changes that make good use of some of the data being collected in the Sacramento River above the Delta. Updating the JPE and continuing refinement of the salmon decision tree will improve EWA process, as well as the general process of managing take at the state and federal intakes.

We understand that time available for these workshops is limited, thus not all areas of possible interest can be covered. We believe steelhead and San Joaquin (Merced, Tuolumne and Stanislaus rivers) and east side stream (Mokelumne and Cosumnes) emigrants need to be considered in more detail - perhaps as part of our recommendation below. Chinook salmon in the San Joaquin basin are now candidate species and their numbers indicate we need to take measures to enhance runs to this system. It might be that a good explanation and synthesis of the VAMP study results would provide an adequate understanding of the benefits of the use of EWA water during VAMP to protect these runs.

Many recommendations came out of the workshop either as conclusions of individual talks or during discussions. Instead of enumerating these, we present below our suggestions for what to do in two categories varying by time frame.

The Next Two Years

Next year's salmonid workshop. Next summer we will have been through three seasons using EWA water to protect sensitive fish. Looking at it another way, after the 2002-2003 season there will be one more year before the four-year EWA evaluation period is up. The first two years of salmonid workshops have been conducted in a conference format. We would like to design next year's workshop to involve more actual work. Several topics are, or can be by then, ripe for a group effort at solving some problems. This will take considerable preparation. We hope that topics will be discussed only to the extent that data are available at the workshop. Potential topics or subtopics include:

1). *Survival of salmon from eggs to smolts entering the Delta.* What can we learn from the various upstream monitoring programs that will help us understand how naturally-spawned juvenile salmon respond to flow, temperature and other environmental factors? These programs include:

    a). Spawning surveys

    b). Screw-trap sampling at various locations

    c). Beach seine sampling in the Sacramento River.

    d). Analysis of survival to Chipps Island and the ocean fishery of Coleman National Fish Hatchery late-fall Chinook released in Battle Creek.

    e). Temperature, turbidity and flow monitoring data collected at various points along the river.

2). *Movement of juvenile Chinook through the Delta.* Given the combination of results from coded-wire tagging studies, radio-tagging, and observations of naturally produced fish, develop models of the movement of juvenile Chinook salmon through the delta.

3). Direct and indirect project-related mortality of Sacramento-origin juvenile Chinook salmon moving through the Delta. This will be one of the key areas to be considering the impact of the EWA on salmon. Some of the important subtopics in the general area are.

  a). *The Delta action 8 studies.* It appears that we have about peaked on increasing our understanding of through-Delta survival of juvenile Chinook salmon by the use and interpretation of these mark-recapture studies. We recommend that Ken Newman summarize all of his analyses related to through Delta survival and present the information orally to the group or in a paper. We also suggest that there may be different approaches to analyzing these and other data to help sort out direct and indirect mortality in the Delta. These analyses may lead to additional mark-recapture studies or new techniques for assessing project-related indirect losses of juvenile Chinook salmon emigrating from the Sacramento River basin.

  b). *The role of Georgiana Slough and the Delta Cross Channel on salmon survival as these channels affect the amount of water entering the Delta from the Sacramento River.* Recent information has indicated that Georgiana Slough may be more important than one would think based strictly on the amount of water entering the slough from the Sacramento River.

  c). *Take at the federal and state facilities.* The entire salvage and take estimation process is a critical part of the EWA allocation process and may be ripe for re-examination.

4). Can we develop robust and realistic estimates of confidence limits for all of the measurements and indices reported in support of EWA, especially the JPE?

5). Steelhead in all of its mystery.

6). San Joaquin Basin and East-side streams - role of EWA water used to support VAMP in protecting emigrating juvenile Chinook salmon.

7). The relative importance of the ocean recreational fisheries and the ocean environment itself in controlling abundance of Central Valley Chinook salmon.

We recognize that the list contains a large number of complex topics but believe they must all be dealt with in some manner before we are required to evaluate the benefits of the EWA. The workshops could be organized in such a way that the set of scientists would vary from workshop to workshop would and thus distribute the load.

Long-term Activities

We reiterate concerns both of us have expressed in the past about the state of salmon biology in the Central Valley, both that used to support EWA and the general topic. There is a lot of activity in monitoring and research on salmonids, and in many respects the quality of this work keeps improving. However, at present there is no cohesive program on salmon biology, little university involvement, and little in the way of system-wide or life-cycle synthesis of these populations. What we have instead is a piecemeal approach to a very complex set of problems. There are people working on the ocean fishery, on spawning and rearing in specific streams, and on migration through the Delta. Almost nobody is attempting to integrate these parts into a whole, nor is there any effort to identify missing pieces in a systematic way. And although there has been an increase in communication among scientists working on different aspects of the salmonid life cycle, this communication is far from universal, and much too infrequent to be very effective.

We envision three areas in which the state of knowledge used to support EWA and salmonid restoration and protection might be improved. These are discussed below in increasing order of complexity, expense, and time scale.

1). The CALFED Science Program is setting an example by establishing regular, high-quality scientific review of its activities, both for the EWA and other issues. We hope that the management agencies will follow that lead and work with the Science Program to set up reviews of some of the major efforts going on in the Central Valley. These would include:

   a). Spawning surveys.

   b). Outmigrant surveys using rotary screw traps and other techniques.

   c). Mark-recapture experiments using coded-wire tagged fish in the Delta and elsewhere.

2). There is a massive amount of data on various aspects of the system, most of which have not been thoroughly analyzed. To get a handle on these data and convert them into knowledge will require people with skills in data analysis and an understanding of the setting and the life cycle of salmon. This would entail a program of a handful of people tasked with making sense of this immense data set. This might follow the model of the National Center for Ecological Analysis in Santa Barbara, or it could involve the Center directly. The goal of this effort would be to bring the analysis to a state commensurate with the quality and quantity of the available data.

3). We think it may be time to design and build a major research program on salmon of the Central Valley. This program would involve both university and agency researchers, and would be organized around one or more models of the life cycle or of particular aspects of the life cycle. The proposed coldwater fishes chair at UCD could become a key program component. To our knowledge this approach has not been tried before in this field, but there are examples in oceanography (e.g., Global Ocean Ecosystem Dynamics or GLOBEC; Joint Global Ocean Flux Study, JGOFS) and in the National Science Foundation's Long-term Ecological Research program (LTER). Before embarking on such a course we should investigate the various models and their success rate, and also complete a substantial data analysis to prepare for the design of ongoing research.

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Agenda

2002 Salmonid Workshop
July 23-24, 2002

July 23, 2002

Introduction . . . . Bruce DiGennaro, facilitator

Improving the Juvenile Production Estimate . . . . Mike Mohr

Introduction to the EWA . . . . Jim White and Roger Guinee

Summary of 2001–2002 EWA Actions . . . . Roger Guinee

Decision Tree Update . . . . Sheila Greene

Juvenile Production Estimate . . . . Bruce Oppenheim

What Happened to Winter Chinook in 2001–2002? . . . . Jim White

Explaining High Variability in Take at the Pumps . . . . Alice Low

Relation Between Exports and Relative Survival
of Juvenile Chinook Moving Through the Delta . . . . Pat Brandes

Use of Radio Tags to Follow Salmon Movement . . . . Dave Vogel

July 24, 2002

Working Sessions

- Juvenile Production Estimate
- Delta smolt survival
- Decision Tree

Attendees

Aceituno, Mike .... NMFS
Adams, Pete .... NMFS
Birk, Serge .... CVP Water Assoc.
Boardman, Tom .... San Luis and Delta-Mendota Water Association
Bran, Marina .... DFG
Brandes, Pat .... USFWS
Bratcher, Tricia .... DFG
Brown, Randy .... CALFED
Burmester, Rick .... USFWS
Cadrett, Paul .... USFWS
Cantrell, Scott .... DFG
Chappell, Erin .... DWR
Daniel, Dick CH2MHill
Fleming, Craig .... USFWS
Fong, Bellory .... CALFED
Foss, Steve .... DFG
Fujimura, Bob .... DFG
Fullerton, Dave .... Metropolitan Water District of Southern California
Gaines, Philip .... USFWS
Greene, Sheila .... DWR
Greenwald, Glenn .... USFWS
Guinee, Roger .... USFWS
Hamilton, Andrew .... USFWS
Hanson, Larry .... USFWS
Hindman, Nick .... Western Area Power Admin.
Icanberry, John .... USFWS
Ingram, Campbell .... CALFED
Johns, Jerry .... DWR
Kapahi, Gita .... SWRCB
Kimmerer, Wim .... SFSU
Lecky, Jim .... NMFS
Lee, Melissa .... DWR
Liu, Qingin .... DFG
Long, Jim .... DWR
Low, Alice .... DFG
McLain, Jeff .... USFWS
Miller, B.J. .... SLDMDWA
Miyamoto, Joe .... East Bay Municipal Utility District
Olah, Ryan .... USFWS
Oppenheim, Bruce .... NMFS
Pacheco, Victor .... DWR
Petit-Polhernus, Tracy .... DWR
Poage, Victoria .... USFWS
Poytress, Bill .... USFWS
Ramirez, Tim .... The Resources Agency
Rectenwald, Harry .... DFG
Reyes, Pamela .... USFWS
Rodegerhts, Henry .... CFBF
Rooks, Heidi .... DWR
Rutter, Sylvia .... DWR
Shelvock, Don .... DWR
Shum, K.T. .... East Bay Municipal Utility District
Sitts, Rick .... Metropolitan Water District of Southern California
Snow, Jim .... Westlands Water District
Sullivan, Bernice .... Friant Water Users Assoc.
Thabault, Mike .... USFWS
Titus, Rob .... DFG
Tucker, Mike .... NMFS
Vogel, Dave .... Natural Resources Scientists
Walter, Hanspeter .... DWR
Webb, Kim .... USFWS
White, Jim .... DFG
Williamson, Sam .... USGS
Wilson, Don .... DWR
Wuench, Nissa .... Surface Water Resources, Inc.